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AN

INTRODUCTION

TO

LINEAR DRAWING;

TRANSLATED FROM THE FRENCH OF

M. FRANCŒUR;

WITH ALTERATIONS AND ADDITIONS TO ADAPT IT TO THE

USE OF SCHOOLS IN THE UNITED STATES.

TO WHICH IS ADDED,

THE

ELEMENTS

OF

LINEAR PERSPECTIVE;

AND

QUESTIONS ON THE WHOLE.

BY

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BOSTON:

HILLIARD, GRAY, LITTLE, & WILKINS.

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1828.

MUNROE & FRANCIS, PRINTERS.

INTRODUCTION.

An elementary treatise on Drawing, adapted to the use of common schools, can not but be well received. Besides the professions which make the art of drawing their particular study, anatomists, naturalists, mechanicks, travellers, and indeed all persons of taste and genius, have need of it, to enable them to express their ideas with precision, and make them intelligible to others.

Notwithstanding the great utility of this branch of education, it is a lamentable fact, that it is seldom or never taught in the publick schools, although a very large proportion of our children have no other education than these schools afford. Even in the *private* schools where drawing is taught, it is too generally the case that no regard is paid to the geometrical principles on which the art depends. The translator appeals to experience when he asserts, that not one in fifty of those who have gone through a course of instruction in drawing, can do more than copy such drawings as are placed before them. Being ignorant of the certain rules of the art, (and they are the most certain because mathematical) they are always in leading strings, and, unless endowed with uncommon genius, never originate any design, and rarely attempt to draw from nature. It is to remedy this defective mode of teaching, that the

translator has been induced to present this little work on the elements of drawing, to the American publick.

Most of our faculties, when exercised, may attain to a surprising degree of perfection. A precision may be acquired by the eye and hand, almost equal to that of ordinary instruments. With this view, the society for the improvement of elementary instruction in France, directed some of their most distinguished members to procure a work on the art of drawing, which should be applied to the system of mutual instruction, there the national system. The following treatise is, in a great measure, a translation of that approved by them. It is not intended for a treatise on the art in all its numerous branches, but merely the *linear*, and, of course, the fundamental and most useful part of it.

The geometrical figures are arranged according to the difficulty of their execution, rather than in the order of theorems.

Each figure is accompanied with suitable explanations, so that the teacher or monitor will easily comprehend them, and be able to teach them to his classes, without much previous acquaintance with the art.

The pupils are each furnished with a slate and pencil. The monitor directs what figure shall be drawn, and if the pupils are not all furnished with this treatise, he chalks the figure on a board, painted black for the purpose, and suspended where all can see it. The slates are then examined by the monitor, and precedence is given to whichever pupil has executed the figure best.

The instructer should select a sufficient number of the most skilful for monitors, who should be under his

immediate instruction. As soon as they have become expert in drawing the figures of the first class, a second may be formed to be instructed by the first class, (which now becomes the second) and so on to the sixth. The highest class under the master, may consist of about fifteen pupils. The lower classes may consist of any number, but for every six or eight scholars there should be a monitor.

The first class draw right lines, angles, parallels, perpendiculars and triangles.

The second class draw polygons, and polyedrons, or solid figures of many sides.

The third class make circles, and *regular* polygons.

The fourth draw a protracter, make angles of a given opening, draw ellipses, cylinders, cones, spheres, &c.

The fifth apply the preceding figures to architectural drawings, vases, and tasteful ornaments.

The sixth class draw the orders of architecture, and such other objects as an ingenious instructer shall direct.

If the school do not consist of more than 30 or 40 pupils, there will be no need of employing as monitors any but the highest class.

The children should not be permitted to draw on *paper*, until they have become thoroughly acquainted with the figures of the five first classes. Before they attempt the sixth, they may be permitted to review the five preceding classes, drawing the figures on paper with a lead pencil.

The pupils are not to be allowed the use of a rule, or any other instrument; but the monitor, to correct and prove their figures, may be furnished with a rule,

dividers, square, and protracter or graduated semicircle. The rule should be a good one, with the inches and tenths of inches marked on it, that, when the pupils have become expert in making the figure, the difficulty may be increased by requiring the whole, or some part of the figure, to be of a given length or dimension.

On most rules in common use, the inches are divided into quarters and eighths, but as it is our plan to apply Geometry to *decimal* arithmetick, such rules as are divided into tenths should be preferred. When the simplicity of decimal calculations is so evident, it is to be regretted that *all* our *measures* are not subdivided into decimal parts, as our *currency* is, and why our government should set so good an example in one particular, and neglect all the rest, it is not easy to determine.

Although this treatise was originally designed for schools of mutual instruction, still a slight examination of it will show that there is nothing which unfits it for use in schools on any other plan. If the pupils are all taught, and their drawings examined by the instructer, they will do well; but if they are likewise required to examine and correct each other's work, they will do better; they will acquire a familiarity with the figures, and an exactness in execution, to which mere *learners* seldom attain.

PREFACE

TO

THE SECOND EDITION.

The favourable reception of the first edition of this Treatise, has induced the Translator to revise it carefully, and to add to it a Second Part, containing the elements of *Perspective Drawing*, to which the First Part is a good introduction.

Questions, also, upon the more important parts of the book are added; and the Translator hopes that this more correct and enlarged edition will meet with the same favour that a liberal publick has bestowed upon its predecessor.

Dec. 1827.

CONTENTS.

PART FIRST.

PART SECOND.

PART FIRST.

LINEAR DRAWING.

FIRST CLASS.

The first class only draw right lines, triangles and perpendiculars. The corrections are made with a rule, and dividers.

The four first figures drawn above, relate particularly to the first eight propositions. To ascertain if the line be straight, let the monitor draw a line through it or near it with a rule. To ascertain if a line be cut into equal parts, measure the parts with the dividers, if the eye be not sufficiently practised to detect the errors without their assistance.

PROPOSITIONS.

1. *Draw a right line (that is, a straight line.)* fig.1.

2. *Draw a right line and divide it in the centre.* fig.2.

3. *Draw a right line and cut it into quarters.* fig.3.

4. *Draw a right line and lengthen it as much farther.* fig. 2.

5. *Draw a right line and continue it twice its length.* (fig. 4.)

6. *Draw a right line and lengthen it three times its length.* (fig. 3.)

7. *Cut a right line into three equal parts.* (fig 4.)

8. *Cut a right line into six or eight equal parts, and so on.*

It will be a useful exercise at this stage of the business, to show the parts of a line when divided. Thus, if required to show how much three quarters of a line are, the pupil must find one quarter, and the rest of the line will be three quarters. To find three fifths of a line, cut the line into five parts, and take three of them. A very correct idea of fractions may in this way be communicated.

(5)

9. *Draw a line one inch long, then two, three, four, five, six.* (fig. 5.)

10. *Draw a line and divide it into inches.*

It is of no consequence what the length of the line is. Begin at the left and mark as many whole inches as there may be.

11. *Draw a horizontal line.*

A horizontal line is one drawn from left to right, or from right to left. The surface or top of a bowl of water is horizontal or level.

(6)

12. *Draw a perpendicular line.* (fig. 6.)

A perpendicular or vertical line is one perfectly upright, as a string, with a weight at the end of it, will hang from a nail, or from the hand.

In making horizontal lines, the pupil should make them parallel to the top or bottom of his slate or paper, and in making perpendiculars they should be parallel to the sides of the slate or paper. *Parallel* lines are lines running in the same direction equally distant from each other in every part; thus, the horizontal lines in figures 1, 2, 3, 4, are parallel to each other. Lines may be drawn parallel at any distance from each other.

18. *Draw two parallel horizontal lines, then three, four, five and six.*

14. *Draw two parallel perpendiculars, then three, four, five and six.*

15. *Draw an oblique line and cut it into two, four, three and six parts.*

An oblique line is one between a horizontal and a perpendicular; that is, a *leaning* line.

16. *Draw two parallel obliques, then three, four, five and six.*

17. *Draw parallel lines an inch apart, then half an inch, a quarter, &c.*

18. *Draw a perpendicular, and cut it into two, three four, five, six equal parts.*

It is difficult to cut a *perpendicular* into equal parts, because of an optical deception which leads us to think the upper parts shorter than they really are. This must be guarded against.

19. *Join two dots or points by a right line.*

The pupil will move his pencil two or three times from the left dot to the right, before he draws the line. This precaution is more necessary when the operation is performed on paper than when on a slate, where it may be erased if wrong.

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(8)

20. *Make an acute angle.* (fig. 7.)

Care must be taken to distinguish an *angle*, from what is called its *point* or *apex*. The *angle* is the *opening* between two lines that meet, and the *point* or *apex* is the point where the lines meet. A pair of dividers forms a number of different angles, by being opened more or less.

It is this *opening* of the sides which determines the size of the angle, and not the *length* of the sides, which, if lengthened out ever so far, would not affect the size of the angle, because the opening will only be the same part of a a great circle that it was of a small one.

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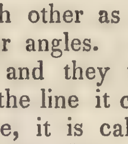
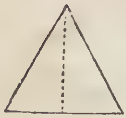


Imagine two lines which cross each other as in figures 9 and 10. They will make four angles. These are *right* angles if they are *equal*, and they will be equal if one line is perpendicular to the line it crosses. If the angle be *less* than a *right* angle, it is called an *acute* angle; if more, it is called an *obtuse* angle. *Acute* means sharp, and *obtuse* means blunt.

21. *Make an obtuse angle.* (fig. 8.)

22. *Make an acute angle with the opening turned upward, downward, to the right and to the left.*

23. *Make a triangle.* (fig. 11.)

(11) 

Close the space between the sides of an angle with a right line, and you make a triangle, a figure which has three angles and three sides.

The *base* is the side on which the triangle is supposed to rest.

The *apex* of a triangle is the point opposite to the *base.*

The *height* of a triangle is a perpendicular drawn from the *apex* to the *base.* In the figure it is shown by the dotted line.

A triangle is called *Isoceles* when *two* sides are equal. If all *three* of the sides are equal, it is *Equilateral,* (which word means *equal-sided ;*) and if all the sides are *un*equal, it is called *Scalene.*

24. *Raise a perpendicular on a horizontal.* (fig.9.)

This will produce *right angles,* as we have before remarked. To ascertain if the angle be exact, take a piece of what is called bonnet paper or thin pasteboard, cut it round and then cut the round piece into quarters. Each quarter will have two sides at right angles, and by inserting the *apex* into the opening of the angle drawn by the pupil, any incorrectness will be detected. A small brass or iron *square* will serve the same purpose, but does not satisfactorily show that a right angle is equal to a quarter of a circle, which is also called a *quadrant.*

25. *Cross a right line with a perpendicular.* (fig.10.)

The right line should be drawn in various directions, to show the pupil that a perpendicular may be raised on any right line, whether horizontal or oblique.

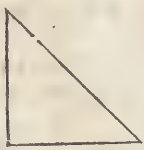
26. *Draw a rectangular, or right angled triangle,* (figs. 12 and 13.)

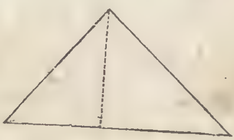
This is a triangle of which one of the angles is a right angle, as the lower left hand one in fig. 12, and the top one in fig. 13. The base may be horizontal or inclined.

27. *Make a rectangular isoceles triangle.*

There is no difference between this and figures 12 and 13, except that in an isoceles triangle, two of the sides must be of equal length. In fact, fig. 12 is an isoceles.

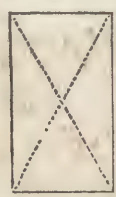
Figure 13, though rectangular, is a scalene also.

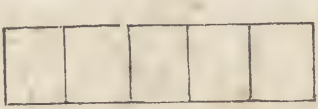
(12) 

 (13)

28. *Draw a rectangle.* (fig. 14.)

A *rectangle* is properly a figure with four sides, of which each two opposite sides are equal and parallel, and of which *all* the angles are right angles.

(14) 

 (15)

The lower side is the *base*, and the right or left side is the *height*.

To ascertain its correctness, the Monitor may examine every angle with his *quadrant* of pasteboard, or he may with his dividers see if the left hand upper, and

right hand lower angles are as far apart as the other two angles are. Figure 14 is what is often called a *long* or *oblong square.*

29. *Make a rectangle, and cut it into equal right angles.* fig. 15.

(16)

(17)

30. *Make a parallelogram, and mark its height.* (fig. 16.)

The *parallelogram*, like the rectangle, has its opposite sides parallel, but none of its angles are *right.* The *height* is a perpendicular dropped from the top to the base, and is marked by the dotted line in the figure.

31. *Make a square.* fig. 17.)

This figure has all its sides equal, and all its angles *right.*

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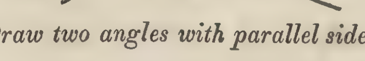


(19)

32. *Draw two angles with parallel sides.* (figs. 18 and 19.)

Two angles, as in figure 18, are called parallel, not because their sides are of equal length, but because their openings and points correspond exactly. Fig. 19 is designed to exercise the pupil in making parallel angles in various positions.

33. *Draw obliques equidistant* (that is, *equally distant) from a perpendicular.*

Draw first a horizontal, raise a perpendicular on its centre, and then draw a line from the top of the perpendicular to each end of the horizontal. The figure will then be an *isoceles triangle*, as in fig. 11.

34. *Make a scalene triangle.* (fig. 13.)

As it is not difficult to make a triangle of unequal sides, it will be well for the monitor to prescribe the length of one or more of them. Thus he may say: "Make a scalene triangle, of which the three sides shall measure one inch and two tenths; one inch; and eight tenths of an inch."

35. *Make an equilateral triangle.* (fig. 20.)

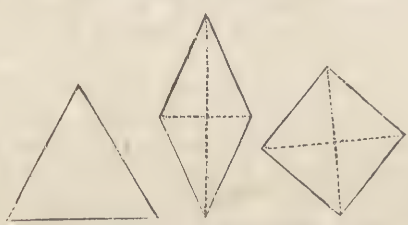
After the pupil makes the figures exactly, let the length of the sides he given, as one, two, three, &c. inches. Then require the point to be under the base, turned to the right, &c.

36. *From a given point draw a perpendicular.*

First draw a right line, then make the proposed point, and lastly draw the perpendicular.

27. *Raise a perpendicular on the end of a right line.*

(20) (21) (22)



38. *Make a Rhomb or Lozenge.* (fig. 21.)

The four sides are equal as in the square, but the angles are not *right* angles. To draw this figure, make a right line, cross it with a perpendicular, like the dotted lines in the figure, and then draw the sides.

If the Rhomb or Lozenge have all the angles equal, the figure is merely a square placed obliquely, as in fig. 22.

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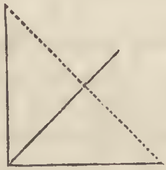

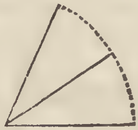

(24)

39. *Cut a rectangle into halves.* (fig. 23.)

This will make two angles, whose exactness may be tested by an *eighth* part of a circle of pasteboard, the rectangle being quarter of a circle, as was stated under Prop. 24.

40. *Cut an acute angle into two equal parts.* (fig.24.)

41. *Double an angle.*

Make an angle of any size, and then make another of the same size by the side of it. Suppose the lower angle of fig. 24 to be made first, then by making the upper right line, the angle will be doubled.

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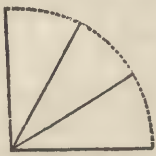
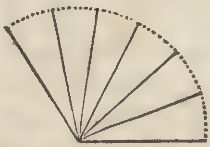




(26)

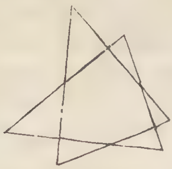
42. *Triple an angle.* (fig. 25.)

43. *Cut an angle into three equal parts.* (fig. 25.)

44. *Cut an angle into six equal parts.* (fig. 26.)

These three propositions need no explanation.

SECOND CLASS.

(1)   (2)

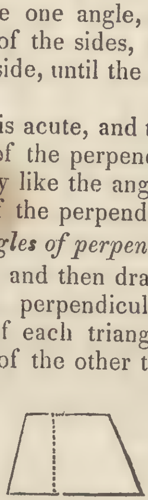
1. *Make two triangles of perpendicular sides.*

After having made one angle, the pupil will draw a perpendicular to one of the sides, and then a perpendicular to the other side, until the perpendiculars cross each other.

One of the angles is acute, and the other obtuse; and if you lengthen one of the perpendiculars, a new angle will be formed exactly like the angle first made, as the dotted continuation of the perpendicular in fig. 1 shows.

2. *Make two triangles of perpendicular sides.* (fig. 2.)

Make one triangle, and then draw a perpendicular to each side, until the perpendiculars touch and form angles. Each side of each triangle must be perpendicular to some side of the other triangle.

(3) 

3. *Make a trapezoid.* (fig. 3.)

A trapezoid has four sides, of which, two, called the bases, are parallel. In the figure, these are the upper and lower sides. The height is a perpendicular from base to base. As this figure is easily made, the length of the bases and the height may be given: thus, "Make a trapezoid whose height shall be one inch, and whose bases shall be an inch and a half and two inches." When no two of the sides are parallel the figure is called a *Trapezium.*

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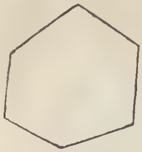

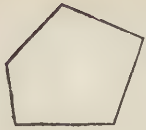

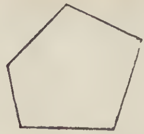

4. *Make a six sided polygon of unequal sides.* (fig.4.)

The word polygon means *many-angled.* To make a polygon, the best method is, first to place dots at the angles and then draw right lines from dot to dot.

5. *Make a five sided polygon of unequal sides.* (fig.5.)

6. *Make two polygons of unequal but parallel sides.* (figs. 5 and 6.)

7. *Make a six sided polygon of equal sides.*

8. *Make a five sided polygon of equal sides.*

A polygon of equal sides is called a *regular polygon.*

9. *From one point of a polygon draw diagonals, and then draw a parallel polygon within the first.* (fig.7.)

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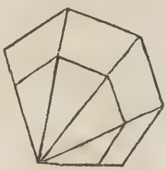

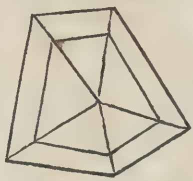

(8)

After drawing a polygon, from either of the points carry right lines to all the rest, thus making several triangles. These lines are called *diagonals.* Then you have only to draw parallels to the several sides from diagonal to diagonal.

To vary the exercise, let the pupil draw a polygon *outside* of the first drawn. He will then only have to lengthen the diagonals.

10. *Draw a polygon, and from a central point draw diagonals, then draw a parallel polygon within and outside of the first drawn.* (fig. 8.)

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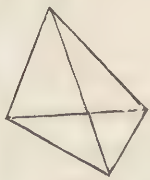

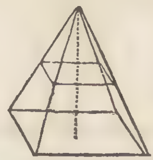

(10)

11. *Make a triangular pyramid.* (fig. 9.)

First draw the triangle which forms the base, then place a dot for the point or apex, and draw right lines from the point to each angle of the base.

12. *Draw a quadrangular (or four angled) pyramid,* (fig. 10.) *then cut it by a plane parallel to its base.*

The process is the same as in the preceding figure. The plane, or parallel to the base, must be the last thing done. The *height* of the pyramid is a perpendicular dropped from the apex or summit to the base. The pupil must be careful to distinguish the front lines from the back lines of the figure.

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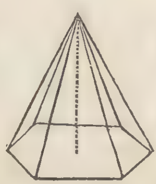

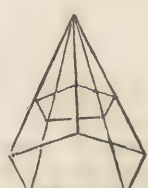

(12)

13. *Make a six sided pyramid.* (fig. 11.)

14. *Make a five sided pyramid.* (fig. 12.)

15. *Make a five sided pyramid, and cut it by a plane parallel to the base.* (fig. 12.)

Note. When the base of the pyramid is a regular polygon, and the *height* falls upon the centre of it, the pyramid is upright and regular; such are figures 10, 11 and 12.

16. *On two polygons of parallel sides, raise a pyramid.* (fig. 12.)

This is merely another way of performing the last figure, by drawing both polygons before you draw the trunk of the pyramid.

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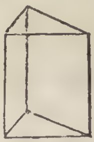

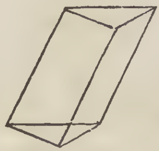

(14)

17. *Make an upright triangular prism.* (fig. 13.)

A *prism* is a body formed from two equal and parallel polygons, whose corresponding points are joined by lines, all parallel, and equal to each other; such are figures 13 to 20 inclusive.

The *height* of a prism is a perpendicular to the two bases. A prism is said to be *upright* when its sides are perpendicular, and oblique when its sides lean or are inclined.

18. *Make an oblique triangular prism.* (fig. 14.)

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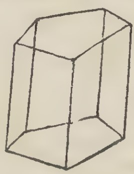

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19. *Make an oblique five sided prism.* (fig. 15.)

20. *Make an upright parallelopiped.* (fig. 16.)

When the bases of the prism are *parallelograms*, the body is called a parallelopiped. All the six faces are then parallelograms, and the two opposite faces are equal.

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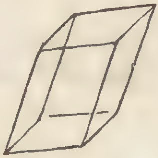

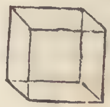

(18)

21. *Make an oblique parallelopiped.* (fig. 17.)

22. *Make a Cube.* (fig. 18.)

The cube is a parallelopiped, all of whose faces are equal squares, and each placed at right angles with the contiguous or next squares.

A cube is a *solid square*, but it will be perceived, that in consequence of perspective, only the front and back faces appear square. These two faces should be traced first, and the rest will easily be added. Dice are cubes.

23. *Draw an oblique cube.* (fig. 17. if you make its sides equal.)

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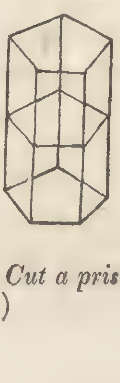

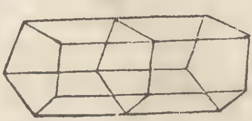

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24. *Cut a prism by a plane parallel to its bases.* (fig. 19.)

A *Plane* is a *level.* Place one die upon another, and together they make a prism, cut by a plane where the separation between the dice is.

25. *Make a six sided prism, and double it by lengthening it.* (fig. 19.)

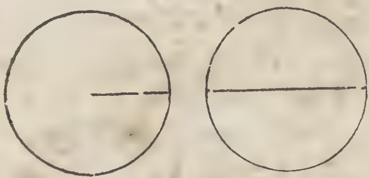
When one die is put upon another, the first die is doubled in length.

26. *Make a five sided prism, and cut it by three planes parallel to its base.*

A long prism may be drawn and cut as in Prop. 24, or a short prism be first made and lengthened as many times as you please.

27. *Draw a five sided prism in a horizontal position.* (fig. 20.) *Cut it by a plane parallel to its base.*

THIRD CLASS.

(1)  (2)

1. *Describe a circle and mark its centre.* (fig. 1.)

By constant practice the pupil will be able to draw a circle, and mark its centre with great exactness. The monitor with a pair of dividers will prove it. The pupils in the Monitorial School have various methods of marking circles, without the aid of dividers, the most

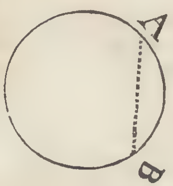
expeditious of which is, holding the pencil between the thumb and fore finger, pressing the nail of the fore finger hard upon the slate or paper, and then turning the slate round. But as this exercises the judgement but little, and the eye still less, it should only be allowed when despatch is required.

A *radius* is a right line drawn from the centre of a circle to any part of its circumference. (fig. 1.)

A *diameter* of a circle is a right line drawn from one side of the circumference through the centre to the opposite side. (fig. 2.)

An *arc* of a circle is any portion of its circumference. Thus in figure 3, that part of the circumference between

(3)



(4)

A and B is an *arc*, and a right line drawn from one end of an *arc* to the other is called a *cord*. In fig. 3, the cord is represented by the dotted line.

The monitor will mark a centre, or draw a radius for the two following questions.

2. *Make a circle round a given centre.* (fig. 1.)

3. *Describe a circle round a given radius.* (fig. 1.)

4. *Cut a circle by two perpendicular diameters.* (fig. 4)

5. *Cut a circle into eight equal parts.* (fig. 4.)

To do this, cut the circle into four parts, as in proposition 5, and then halve the quarters.

(5)

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(7)

6. *Describe three concentrick circles.* (fig. 5.)

In fig. 5, all the circles have the same centre.

7. *Describe three concentrick circles equidistant from each other.*

8. *Draw two concentrick circles, the diameter of one being three times that of the other.*

9. *Draw an arc of a circle, and mark its centre with a dot.*

The centre of an arc, is the centre of the circle of which the arc is a part.

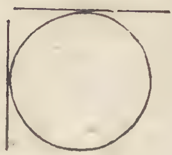
10. *Draw an arc of a given radius.* (fig. 6.)

It is easier to draw a whole circle than merely an arc of it. By placing the dividers on the centre, the monitor will easily test the correctness of the arc.

11. *Cut an arc into two equal parts.* (fig. 6.)

12. *Cut an arc into three equal parts.* (fig. 7.)

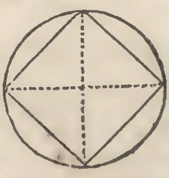
13. *Cut an arc into three smaller ones, and draw the cord of each.*

(8)   (9)

14, *Describe a circle and draw a tangent to it.* (fig. 8.)

Tangent comes from a latin word, which means to *touch.* A *tangent* is a right line which touches a circle, but does not cut any of it off. If a right line be drawn from the centre of the circle or arc to the *point of contact* (that is, the point where the tangent touches the circle) the two right lines, (that is, the radius and the tangent) will be perpendicular to each other. (fig. 9.)

The monitor may test this with his quadrant of pasteboard ; or, marking two places on the tangent at equal distances from the *point of contact*, he may see with his dividers if these points are at equal distances from the centre of the circle.

(10)   (11)

15. *Draw four tangents to a circle, forming a quadrilateral or four sided figure.*

This figure need not form a perfect square, as in figure 10.

16. *Circumscribe or surround a circle with a square.* (fig. 10.)

When the four tangents make right angles with each other, the figure is a square. In other cases, any direction may be given to *two* of the tangents.

In figure 10 we say the circle is *circumscribed* by the square, or the circle *inscribed* in a square.

17. *Inscribe a square in a circle.* (fig. 11.)

When a polygon has all the points of its angles touching a circle, it is said to be *inscribed* in a circle, and the circle *circumscribes* the polygon.

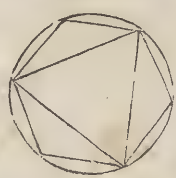
18. *Double an arc of a circle.* (fig. 6.)

This is more difficult than Prop. 11. First draw an arc and mark the centre of its circle, then prolong the arc to two, three, &c. times its former size.

19. *Draw a tangent to a circle from a given point outside.* (fig. 8.)

20. *Draw two tangents to a circle from a given point.* (fig. 12.)

(12) 

 (13)

Observe that in drawing a tangent to a circle in problem 14, any part of the circle may be taken, but when a tangent is drawn from a given point, it can hit but two points of the circle, as in fig. 12.

21. *Cut a circle into six equal parts*, or, in other words, inscribe a regular hexagon in a circle.) (fig. 13.)

The radius of any circle is equal to one side of the hexagon to be inscribed in it. The monitor, therefore,

may measure the radius with his dividers, and then apply them to each side of the hexagon. In other words, the *cord* of an arc, which is the sixth part of a circle, is equal to a radius or half diameter, (usually called a *semi-diameter.)*

22. *Cut a circle into three equal parts, and inscribe an equilateral triangle.* (fig. 13.)

After the hexagon is correctly drawn by problem 21st, it is easy to inscribe the triangle required in this, by drawing a cord between two points of the hexagon.

If cords be then drawn between the three remaining points of the hexagon, another triangle will be formed, whose base will be opposite the base of the other triangle, forming a beautiful figure resembling a star.

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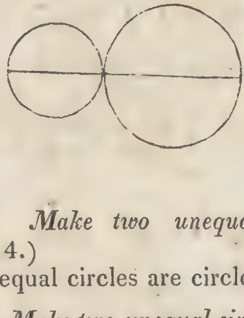


(15)

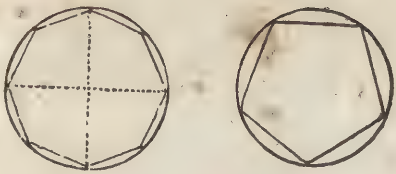
23. *Make two unequal circles tangent outside.* (fig. 14.)

Unequal circles are circles of unequal *size* only.

24. *Make two unequal circles tangent inside.* (fig. 15.)

25. *The centres and the point of contact being given, perform problems 23 and 24.*

The monitor will mark the centres, &c. When the circles touch either within or without, the point of contact and the two centres will be in a right line, and these may be tested with a rule.

(16)  (17)

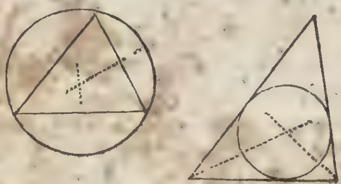
A *regular polygon* has all its sides equal, and all its angles of an equal opening. When such a polygon is inscribed in a circle, the sides are cords of equal arcs, and the points cut the circle into equal parts.

26. *Inscribe a regular octagon in a circle.* (fig. 16.)

Draw two diameters perpendicular to each other, then divide each quarter of the circle into halves by other diameters; then draw arcs from diameter to diameter.

27. *Inscribe a regular pentagon in a circle.* (fig. 17.)

It is difficult by the eye alone to divide the circumference into five equal parts, and the object of this problem is to exercise the pupils.

(18)  (19)

28. *Make a triangle, and circumscribe a circle.* (fig. 18.)

First make a triangle, and then the object is to describe a circle which shall cut each of its three points. To do this, raise a perpendicular on the middle of one

of the sides, and then on the middle of another side. These perpendiculars will cross each other, and *the point of section* (that is, the point where they cut each other) will be the centre of the circle required.

In the figure, the dotted lines show the perpendiculars and centre.

29. *Make a circle, and draw a tangent triangle.* (fig. 19.)

Three tangents to a circle are easily made, but the monitor may increase the difficulty by giving directions to the tangent sides. Thus, let two sides be at right angles, obtuse or acute; let the triangle be equilateral, &c.

30. *Draw a regular pentagon, and circumscribe it with a circle.* (fig. 17.)

31. *Draw a regular hexagon, and circumscribe it with a circle.* (fig. 13.)

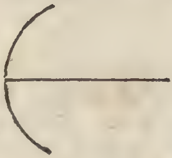
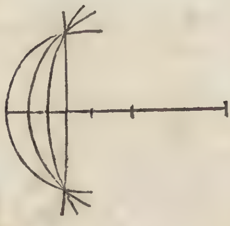
32. *Draw a regular octagon, and circumscribe it with a circle.* (fig. 16.)

In the former problems, the circle was made first, now the polygon.

33. *Inscribe a circle in a triangle.* (fig. 19.)

To find the centre of the circle, draw a line from the middle of either side of the triangle to the apex opposite, then do the same by another side and its opposite apex; the place where these two lines cross each other, will be the centre of the circle to be inscribed. See the dotted lines in fig. 19.

34. *Make an arc which shall pass through two given points.* (fig. 20.)

(20)   (21)

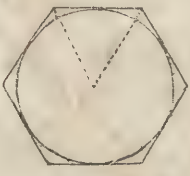
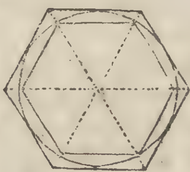
After having marked two points, trace an arc of a circle which shall pass through both of them. The centre must be somewhere on a perpendicular to the middle of a cord which would join these two points.

35. *Make several arcs pass through two given points.* (fig. 21.)

Draw one arc as in problem 34, then a cord from point to point, then a perpendicular to the cord, and then you may make any number of arcs pass through the two points, all of whose centres must be on the perpendicular.

This problem will assist the pupil in drawing the meridians on a map of the globe.

36. *Describe a circle, and circumscribe it with a hexagon.* (fig. 22.)

(22)   (23)

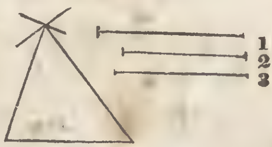
Cut the circumference into six equal arcs, as if you wished to *in*scribe the hexagon. Then draw a radius to each point, and six tangents perpendicular to the radii will form the regular hexagon required. Or, the tangents may be drawn as in fig. 22, where they meet and form an angle on the prolonged radii.

37. *Inscribe and circumscribe a circle with regular and parallel hexagons.* (fig. 23.)

38. *Inscribe a circle in a regular hexagon.* (fig. 22.) This problem is the inverse of the 36th. First draw the hexagon, then describe the circle, touching it on all sides. The centre of the circle may be found by raising perpendiculars on the middle of any two sides until they cross each other. The point where they cross, is the centre.

39. *Make a triangle whose three sides are given.* (fig. 24.)

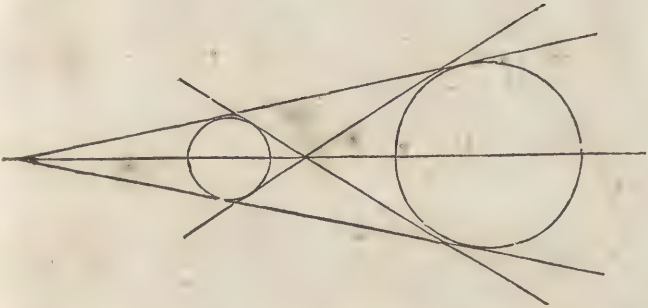
(24)



Trace three right lines for sides. Take one of them, the longest if you please, for the base, and then make a point where you think the other two sides will reach. The difficulty is to ascertain exactly where this point should be. With dividers it may be easily found in the following manner :—After you have drawn the base, open the dividers the length of the next side to be drawn, and placing one foot of the dividers on one end of the base, draw an arc with the other foot. Then taking the length of the third side, place one foot on the other end of the base, and draw an arc which shall cross the former arc : the point where the arcs cross each other is the summit or apex required.

If the two arcs cannot cross, the problem is said to be *absurd :* for no triangle can be made of the given sides. Each of the three sides must be shorter than the two others would be if united.

(1) FOURTH CLASS.



1. *Draw a right line tangent to two circles.* (fig. 1.)

Take either of the right lines in fig. 1. The circles may be placed more or less distant from each other, and may even *intersect* or cut each other. A radius drawn from the centre to *the point of contact* will be perpendicular to the tangent.

2. *Draw four tangents to two circles.* (fig. 1.)

There may be two interior and two exterior tangents. The right line which joins the centres is also the point where the tangents must *intersect* each other.

3. *Add two squares.* (fig. 2.)

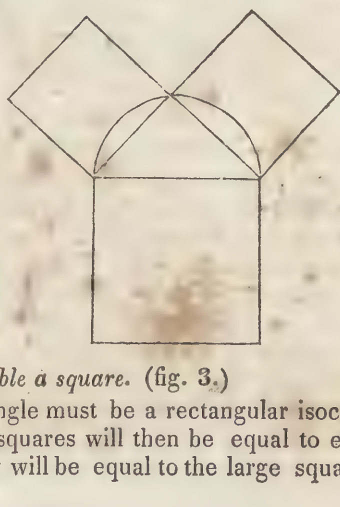
This figure and figure 3, present two rectangular triangles, on whose sides three squares are constructed. The two small squares have this peculiarity, that one of their sides is exactly one side of the triangle, and another is merely a prolongation of the other side of the right angle. If a semicircle be drawn on the greatest side of the triangle, it must touch the apex of the triangle.

It is a fact in geometry, that the greatest of these three squares, contains a surface equal to the other two added together.

(2)

4. *Add two given squares.*

Make a right angle, and on its sides place the sides of the squares. These lengths will be the small sides of your right angled triangle; then draw the longest side, and you have the side of a square equal to the other two.



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5. *Double a square.* (fig. 3.)

The triangle must be a rectangular isoceles, and the two small squares will then be equal to each other, or united they will be equal to the large square.

6. *Cut off a square.* (fig. 2.)

If the great square and one of the small ones be given, it is easy to find the size of the other.

First draw the great side, then the semicircle, then draw from either end of the great side, (which you will notice is the diameter of the semicircle) a cord of the semicircle, which is equal to a side of the given small square. The other cord which will finish the right angled triangle, is the side of the square required.

7. *Take the half of a square.* (fig. 3.)

A perpendicular to the middle of the long side, will strike the semi-circle, and a cord from this point of intersection to either end of the diameter or long side, will give the side of the square, half as large as the great square.

8. *Make a graduated semicircle, usually called a Protracter.* (fig. 4.)

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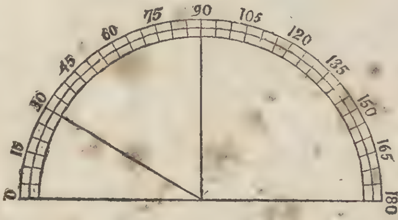

By general consent a circle is divided into 360 equal parts, called degrees. A semicircle of course contains 180 degrees, that is, half of 360.

After having drawn a semicircle and its diameter, draw a perpendicular radius. This radius forms a right angle with the diameter, and cutting the semicircle in two equal parts or quarters of circles, leaves 90 degrees for each of them. If 90 degrees of a circle make a right angle, 45 degrees will make half a right angle, &c.

Or by another method. A radius, if made a cord of the semicircle, will allow three cords, each of which will contain 60 degrees; halve these arcs, and you have arcs of 30 degrees; halve the arcs of 30 degrees, and you have 15 degrees; cut these into three equal parts, and you have 5 degrees; then divide the arcs of five degrees into five parts, and you have the 180 degrees of the semicircle.

Whether the circle be large or small, it is divided into the same number of degrees; for if the radii of a small circle be lengthened out, and a larger circle drawn from the same centre, the radii will form the same part of the large as of the small circle, and the angle between any two radii will be unchanged.

9. *Make an angle of* 30 *degrees on the graduated semicircle.* (fig. 4.)

A radius drawn from the centre to the number 30 on the graduated semicircle, will form an angle of 30 degrees with the diameter of the semicircle. And so for any other number of degrees. It will be seen that any number of degrees less than 90 will make an acute angle, and more than 90 degrees will form an obtuse angle: thus, in fig. 4, 30 degrees form an acute angle, and the remaining 150 degrees of the half circle form an obtuse angle.

Angles, therefore, are measured by their openings. Place the point of angle on the centre of the semicircle, or the centre of the semicircle on the point of the angle, and then by seeing how many degrees the opening of the angle measures on the graduated edge of the semicircle, you will find the size of the angle. If the sides of the angle do not extend to the circumference, you may extend them till they do. If they extend beyond the circumference, measure the angle where the graduated circle cuts the sides.

10. After the pupil has drawn the semicircle, the monitor must require him to draw angles of various sizes, from 1 to 180 degrees. Then, laying aside the semicircle, let him draw angles of various degrees, which the monitor will test by his brass semicircle, or by angles of pasteboard previously prepared : the latter are the handiest if well cut.

11. *Make a sphere and its meridians.* (fig. 5.)

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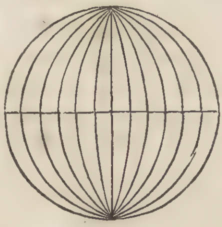
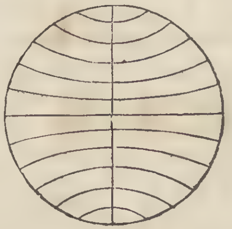




(6)

Describe a circle and draw two diameters perpendicular to each other ; one for the *axis*, and the other for the *equator*, (a circle which goes round the earth at an equal distance from the ends of the *axis*, which ends are called *poles*.) Then draw arcs of a circle, all passing through the poles, and whose centres are consequently on the perpendicular to the axis (that is, the equator) prolonged to the right or left hand. See Class III, problem 35. fig. 21.

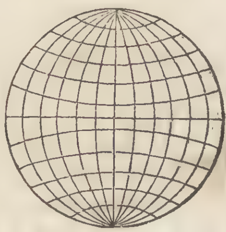
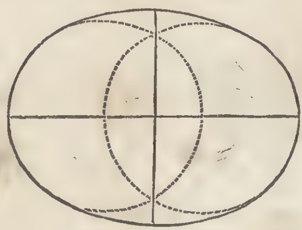
These arcs have their centre as much farther off as they are nearer the axis. Their number is not important, but if five be made on each side of the axis, as in the figure, each of the spaces between them will be just 15 degrees, or one twenty-fourth part of the whole sphere. These arcs in geography are called *meridians*.

12. *Make a sphere and the little circles which run parallel to the equator.* (fig. 7.)

After having described a circle, and its two perpendicular diameters, as in the preceding problem, divide the circle by dots into arcs of, say, 15 degrees ; there will then be five dots and six arcs between the equator and each pole ; then divide the axis into the same number of parts. The next object is to draw an arc through the three points nearest the equator, then through the three next, and so on till all are drawn.

These arcs on a solid globe would be parallel to the equator, but do not appear so on a plane or flat surface. In geography, they are called *Parallels of Latitude.*

If an apple be taken and sliced from side to side, it will exactly represent the circles, which are planes cutting a sphere perpendicular to its axis.

(7)   (8)

13. *Draw a sphere which shall unite the two preceding problems.* (fig. 7.)

14. *Draw an ellipse.* (fig. 8.)

An ellipse is an *oval*, which may be more or less lengthened, as in figures 9 to 13. To make an ellipse : first cross two perpendicular right lines ; the upper and lower halves to be of equal length, and the right and left hand to be equal also. You thus obtain the longest and shortest diameter of the ellipse, called its great and small axis. The next thing is to draw the curved lines as in

the figure. The length of the diameters may be varied at pleasure by the monitor.

There are various geometrical rules for drawing ellipses, but it is not within the scope of our work to notice more than one of the simplest forms of ovals. Draw a circle and mark its centre and diameter. Then on one end of the diameter, draw another circle of the same size intersecting the former. Then opening the dividers the length of the diameter, place one foot on the lower point of intersection, and connect the two circles at top, and then do the same by the other point of intersection and the bottom part of the oval.

A simple and amusing method is, to stick two pins into a piece of paper firmly, at any distance from each other ; tie the ends of a piece of string together, and put the string round both pins. Hold a pencil then at any part of the string, and move it round ; an ellipse will be formed, of which the two pins will be the two *foci* or centres. By lengthening or shortening the string, the figure may be made more or less elliptical.

15, *Draw an oblique cone.* (fig. 9.)

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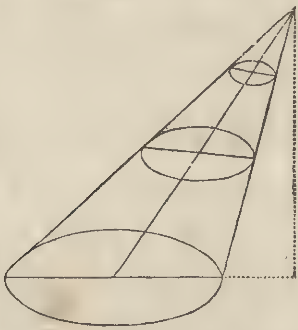

Take a circle for the base, and from some point over this plane or level, draw right lines to the circumference

of the circle, and you have a cone. A cone is, in fact, a pyramid whose base is a circle, and not a polygon. Sugar loaves are cones.

The *height* of a cone is a perpendicular let fall from the top or apex to the base. If this perpendicular fall exactly upon the centre of the base, the cone is *upright*.

The perspective, by changing the apparent dimensions of bodies, gives to the base of a cone the form of an ellipse. The cone presents no other difficulty than the ellipse.

16. *Draw an upright cone.* (fig. 10.)

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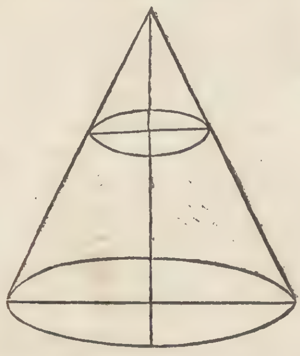


17. *Draw an oblique cone, and cut it by two planes parallel to the base.* (fig. 9.)

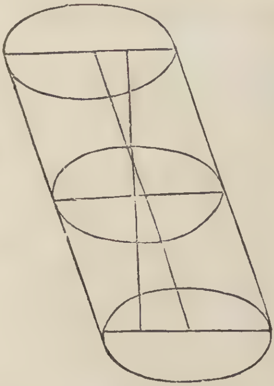
18. *Draw an oblique cylinder.* (fig. 11.)

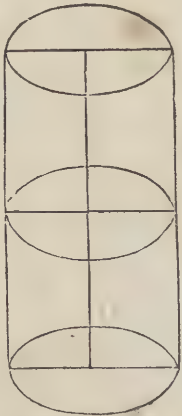
Draw two horizontal lines parallel to each other. Draw two equal circles, of which these shall be diameters. Let a right line go from centre to centre, and it will be the *axis*. Then draw lines from circumference to circumference, and you have a cylinder. A piece of the funnel of a stove is a cylinder. A cylinder is, in fact, a prism whose bases are circles instead of polygons.

The height of a cylinder is the length of the axis, or the distance from one base to the other. If the axis be perpendicular, the cylinder is said to be *upright*.

Here, as in the cone, the laws of perspective change the circles into ellipses. The axes of the ellipses, and that of the cylinder, may be given in inches by the monitor.

(11)





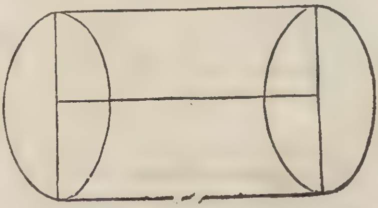
(12)

19. *Draw an upright cylinder.* (fig. 12.)

20. *Cut a cylinder by a section parallel to its base.* (figs. 11 and 12.)

21. *Make a cylinder whose axis shall be horizontal.* (fig. 13.)

(13)

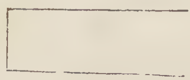


FIFTH CLASS.

The figures of the Fifth Class are formed by the union of such lines as have already been given, viz. horizontals, perpendiculars, and arcs of circles or ellipses.

1. *Draw a fillet.* (fig. 1.)
2. *Draw a bead.* (fig. 2.)
3. *Draw a congee.* (fig. 3.)

(1)



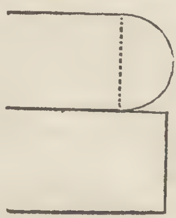
(2)

(3)

These *mouldings*, as they are called in architecture, are so simple as to need no explanation. Horizontals and verticals will be found in them, with circles, of which the dotted lines mark the centre.

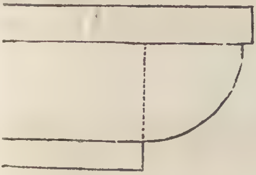
4. *Draw a torus with its plinth.* (fig. 4.)

(4)



The torus, of which the profile is here given, is a large moulding, usually placed at the base of columns. The torus has its diameter, vertical, and parallel, to the axis of the column. The plinth, is the short cylinder which supports the torus.

(5)



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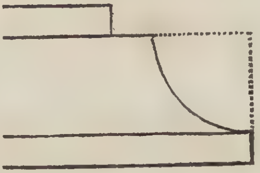
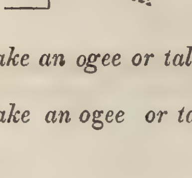
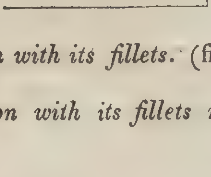


5. *Make a quarter-round with its fillets.* (fig. 5.)

6. *Make a quarter-round reversed, with its fillets.* (fig. 6.)

(7)





(8)

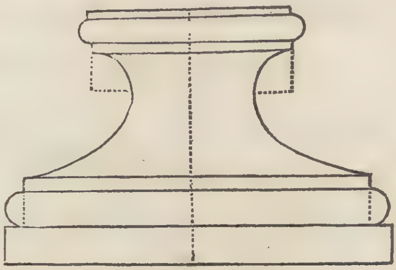
7. *Make an ogee or talon with its fillets.* (fig. 7.)

8. *Make an ogee or talon with its fillets reversed.* (fig. 8.)

The profile of the talon is formed by two arcs of a circle united at their end, and whose centres are on different sides of a right line, which joins their extremities. This line, which is dotted in the figure, is cut in the middle by the arcs, and each half being taken for the base of an equilateral triangle, the summit or apex of the triangle is the centre of the arc. The right line which joins these two summits or centres of the arcs, passes through the point where the two arcs touch at the middle of the first right line.

9. *The monitor must now require the pupil to draw the eight preceding figures, turned towards the left.*

(9)



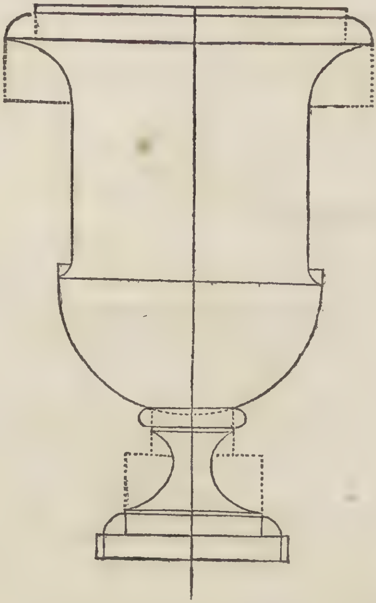
10. *Make a pedestal.* (fig. 9.)

Here the arcs, end to end, belong one to an ellipse, and the other to a circle. The centres and axes are marked.

11. *Make a vase or flower pot.* (fig. 10.)

It will be recollected that this and the preceding figures of this Class, are *flat* representations of *round* objects.

(10)



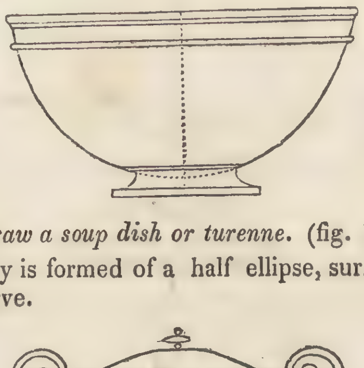
12. *Make a ewer and basin.* (fig. 11.)

Here is a half ellipse joined to two quarter-circles. In the foot of the ewer, its handle and neck, the curves are fanciful. In this, and in all the following figures, the drawings represent *round* bodies.

(11)

13. *Draw a bowl.* (fig. 12.)

Here is a semicircle ornamented with parallel fillets, and placed on a low pedestal.

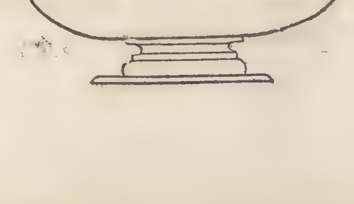


(12)

14. *Draw a soup dish or turenne.* (fig. 13.)

The body is formed of a half ellipse, surmounted by a fancy curve.

(13)



15. *Draw a tea pot.* (fig. 14.)

The principal part is a circle, the handle and nose fanciful.

(14)

16. *Draw a decanter.* (fig. 15.)

The body is formed of an ellipse truncated (that is, cut off) at the two ends.

(15)

The pupils should here be required to exercise their ingenuity and taste in drawing similar figures, without copies, or by having real objects placed before them, such as books in various positions, articles of furniture, &c. &c.

It is left to the Instructer's judgement, whether to take the Sixth Class, the Arithmetical Problems, or the Linear Perspective next. But before attempting either, the student should have gone over all the preceding classes several times on the slate, then with a lead pencil on paper, and lastly, with a pen and ink. Very young children may draw all the preceding figures, but it requires some maturity to draw the rest, and to apply the arithmetick.

SIXTH CLASS.

By the number and complication of details in the figures of this Class, it is evident that they are calculated only for practised pupils, who are skilful in drawing the figures of the five preceding classes, as well with the rule and dividers as without them.

At first the pupils should not draw the details of the frieze, capitals, &c. but merely the large and more important parts, giving them their just proportions, upon which their graceful appearance depends.

There are four modes of arranging the parts of a building, commonly called the four Orders of Architecture, viz. the Tuscan, Dorick, Ionick and Corinthian Orders.

Each has three principal parts, the Column, the Entablature which surmounts it, and the Pedestal which supports it. The pedestal is often omitted, and its place supplied by a plinth only. The order is then reduced to two parts only. Indeed, sometimes the

edifice has no columns, but still it is said to belong to some order, because certain proportions are observed in its parts.

The *Corinthian Order* is distinguished by the richness of the sculptures which decorate its frieze, and which are infinitely varied. The capital of the column is also furnished with two rows of leaves, and eight volutes.

The *Ionick Order* is distinguished by the volutes of its capital.

The *Dorick Order* has its frieze ornamented with triglyps and metopes.

The *Tuscan*, the most plain and solid of all the orders, allows no ornament.

Besides these characteristicks, the different orders are also distinguished by the proportions which regulate their parts, as will be shown hereafter.

Nothing is said here of a fifth order called the *Composite*, because it is composed of the Ionick and Corinthian ; nor is mention make of the Gothick, Attick, German, and Arabick, for a complete treatise on architecture is not intended.

By comparing the different monuments which artists have thought worthy to be considered models, on account of the taste they exhibit, proportions have been noticed in the parts, which have become rules for imitation. Not that there exist in fact, exact and rigorous proportions and rules which are never deviated from, for art has not those fixed rules which are found in the sciences. Certain proportions having been ordinarily observed, and by the consent of all persons of good taste, being found the most suitable, these proportions should be considered as a rule not to be deviated from

without good reasons. The draughtsman, by strictly observing these proportions, is secured from criticism, is sure of doing well, and of obtaining the approbation of judges.

The following are the proportions thus settled:

In *all* the orders, the *entablature* is one quarter as high as the *column*, and the *pedestal* a third.

Each of these three parts is subdivided into three others, viz.

The PEDESTAL into the *Cornice*, *Dye* and *Base*.

The COLUMN into the *Base*, *Shaft*, and *Capital*.

The ENTABLATURE into the *Architrave*, *Frieze*, and *Cornice*.

Care must be taken to proportion the size of the column to its order, its own height, and the height of the edifice it is to ornament.

The height of the Tuscan Column, including its base and capital, is seven times its diameter; of the Dorick, eight times; of the Ionick, nine times; and of the Corinthian, ten times.

The subdivisions are also regulated by this scale. A *radius*, or half diameter of a column, is called a *Module*, which, when once ascertained, determines the height of the frieze, cornice, shaft, &c. These modules are each divided into twelve equal parts in the Tuscan and Dorick orders, and into eighteen in the Ionick and Corinthian.

The number of Modules, or half diameters, which the subdivisions of each order measure, is as follows.

TUSCAN ORDER.

COLUMN.....................14 Modules.

Base - - - - - - - - - - -	1	14
Shaft - - - - - - - - - - -	12	
Capital - - - - - - - - - -	1	

ENTABLATURE...........$3\frac{1}{2}$ Modules.

Architrave - - - - - - - - -	1	$3\frac{1}{2}$
Frieze - - - - - - - - - - -	$1\frac{1}{6}$	
Cornice - - - - - - - - - -	$1\frac{1}{3}$	

PEDESTAL..................$4\frac{2}{3}$ Modules.

Cornice - - - - - - - - - -	$\frac{1}{2}$	$4\frac{2}{3}$
Dye - - - - - - - - - - -	$3\frac{2}{3}$	
Base - - - - - - - - - - -	$\frac{1}{2}$	

In all, 22 Modules and $\frac{1}{6}$, and without the Pedestal, $17\frac{1}{2}$.

The *Intercolumniation*, or space between the bases of two columns, is $4\frac{2}{3}$ Modules.

DORICK ORDER.

COLUMN.....................16 Modules.

Base - - - - - - - - - - -	1	16
Shaft - - - - - - - - - - -	14	
Capital - - - - - - - - - -	1	

ENTABLATURE.............4 Modules.

Architrave - - - - - - - - -	1	4
Frieze - - - - - - - - - - -	$1\frac{1}{2}$	
Cornice - - - - - - - - - -	$1\frac{1}{2}$	

PEDESTAL..................$5\frac{1}{2}$ Modules.

Cornice - - - - - - - - - -	$\frac{1}{2}$	$5\frac{1}{3}$
Dye - - - - - - - - - - -	4	
Base - - - - - - - - - - -	$\frac{5}{6}$	

In all, $25\frac{1}{3}$ Modules, and without the Pedestal, 20 Modules.

The intercolumniation is $5\frac{1}{2}$ Modules.

IONICK ORDER.

Column....................18 Modules.

Base	1	18
Shaft	$16\frac{1}{3}$	
Capital	$\frac{2}{3}$	

Entablature...........$4\frac{1}{2}$ Modules.

Architrave	$1\frac{1}{4}$	$4\frac{1}{2}$
Frieze	$1\frac{1}{2}$	
Cornice	$1\frac{3}{4}$	

Pedestal..................6 Modules.

Cornice	$\frac{1}{2}$	6
Dye	5	
Base	$\frac{1}{2}$	

In all, $28\frac{1}{2}$ Modules, and without Pedestal, $22\frac{1}{2}$. The intercolumniation is $4\frac{1}{2}$ Modules.

CORINTHIAN ORDER.

Column....................20 Modules.

Base	1	20
Shaft	$16\frac{2}{3}$	
Capital	$2\frac{1}{3}$	

Entablature............5 Modules.

Architrave	$1\frac{1}{2}$	5
Frieze	$1\frac{1}{2}$	
Cornice	2	

Pedestal................$6\frac{2}{3}$ Modules.

Cornice	14 parts of a Mod.	$6\frac{2}{3}$
Dye	5 Mod. 4 " " "	
Base	$\frac{2}{3}$ "	

In all, $31\frac{2}{3}$ Modules, or, without Pedestal, 25. The intercolumniation is $4\frac{2}{3}$ Modules.

Thus, to raise an order of a given height, divide the height, as expressed in feet or inches, by the number of modules belonging to the order, and the quotient will be the module or semidiameter of the base of the column. We say the *base*, because it is found that the column is more graceful if it insensibly diminishes towards the top, so as to lose one third of a module in the two upper thirds of the column.

The module, being thus ascertained, is divided into smaller parts, and thus gives the height of all the subdivisions.

A vertical or perpendicular is drawn, on which are successively marked the lengths of the cornice, the frieze, the architrave, &c. On these points, horizontals are drawn, between which will be contained all the mouldings of the order.

Or—if the circumference of the base of a column be measured with a string, and multiplied by 0,159, the module will be found ; and from this, the height of the whole edifice, and of all its parts.

Pediments are triangular structures, whose height may be much varied according to their extent. There are some whose height is a third, fourth, fifth or sixth of the base. This proportion is left to the taste of the artist ; and it is pretty much so with the various mouldings which compose the cornices, capitals, &c.

Pilasters are square columns (parallelopipeds) seldom detached, but fastened to the wall or wainscot, and projecting nearly a third or fourth of a module. In other respects, their ornaments, capitals, base, and all their proportions are regulated by the rules of the order they belong to.

QUESTIONS

RELATING TO

PART 1.

FIRST CLASS.

1. What do the first class draw ?
2. What is a right line ?
3. How may you ascertain whether a line be straight?
4. To cut a right line into four parts or quarters, what must you first cut it into ? (Ans. halves.)
5. To cut a right line into eight parts, how must you proceed ? Ans. Cut it into halves and quarters.
6. What is a horizontal line ?
7. What is a perpendicular line ?
8. In making horizontal lines what must you observe ?
9. In drawing perpendicular lines what must you observe ?
10. What are parallel lines ?
11. What are oblique lines ?
12. What is an angle ? *(page 4.)*
13. What is the point or apex of an angle ?
14. Is it the length of the sides of an angle or the width of the opening that determines the size of the angle ?
15. When do two lines form a right angle ? Ans. When the two sides are perpendicular to each other.
16. What is an acute angle ? Ans. One that is less than a right angle.
17. What is an obtuse angle ? Ans. One that is more or larger than a right angle.

18. What is a triangle ? *(page 5.)*
19. What is the *base* of a triangle ?
20. What is the *apex* of a triangle ?
21. What is the *height* of a triangle ?
22. What is an Isoceles triangle ?
23. What is an Equilateral triangle ?
24. What is a Scalene triangle ?
25. When a perpendicular is raised on a right line, must the right line be a horizontal ? Ans. No. A perpendicular may be raised on any right line whether horizontal or oblique.
26. What is a rectangular or right angled triangle ?
27. What is a rectangular isoceles triangle ?
28. What is a rectangle ? *(page 6.)*
29. What is the *base* of a rectangle ?
30. What is the *height* of a rectangle ?
31. What is a parallelogram ?
32. Has a parallelogram any right angles ?
33. What angles has a parallelogram ? Ans. Two acute, and two obtuse.
34. What is the height of a parallelogram ?
35. How are the sides of a square ?
36. How are the angles of a square ?
37. When are angles said to be parallel ? Ans. When their openings and points are parallel.
38. How are the sides of a Rhomb or Lozenge ?
39. How are the angles of a Rhomb ?
40. How do you proceed to draw a Rhomb ? *(page 9.)*
41. What part of a circle does a right angle form ?
42. If a right angle be cut into two equal parts, what part of a circle will each of these parts be ? *(page 9.)*

SECOND CLASS.

1. How will you proceed in making two angles of perpendicular sides? (*page* 10.)

2. What sort of angles will thus be formed? Ans. One acute and one obtuse.

3. When you make two triangles of perpendicular sides, how must each side of each triangle be?

4. How many sides has a trapezoid?

5. Which two sides of a trapezoid are called the bases?

6. What is the height of a trapezoid?

7. In what does a trapezoid differ from a trapezium?

8. What is the meaning of the word polygon?

9. What is the best method of making a polygon?

10. When is a polygon said to be regular?

11. After you have drawn a polygon, how must you proceed to draw diagonals?

12. When you wish to draw a parallel polygon *outside* of another, what must you do first? Ans. Lengthen the diagonals.

13. What is a triangular pyramid? Ans. One whose base is a triangle.

14. How do you proceed to draw a triangular pyramid?

15. What is the height of a pyramid?

16. In drawing a pyramid, must the front or back lines of the base be uppermost?

17. What is a quadrangular pyramid?

18. When a pyramid is to be cut by a plane, what part must be drawn last?

19. What is the height of a pyramid?

20. In drawing a pyramid, which lines are longest the front or back oblique lines?

21. When the base of a pyramid is a regular polygon, how may you know if the pyramid be upright and regular?

22. What is a prism ? *(page 13.)*

23. Is it necessary that a prism have any particular number of sides ?

24. What is meant by the *height* of a prism ?

25. When is a prism said to be *upright* ?

26. When is a prism said to be *oblique* ?

27. What is a parallelopiped ? Ans. A prism whose bases are parallelograms.

28. What sort of a paralleopiped is a cube ?

29. Which two faces of a cube should be drawn first ?

30. What is meant by a *plane* ?

31. How can you easily represent a prism cut by a plane parallel to its bases ? *(page 15.)*

THIRD CLASS.

1. What is a Radius ? *(page 16.)*
2. What is the Diameter of a circle ?
3. What is the Arc of a circle ?
4. What is a Cord ?
5. How will you cut a circle into eight equal parts ?
6. What is meant by Concentrick Circles ? *(p.17.)*
7. What is meant by the Centre of an Arc ?
8. What does the *word* Tangent mean ? *(p. 18.)*
9. What is a Tangent ?
10. What is the Point of Contact ?
11. When is a circle said to be circumscribed *with* a square ?
12. When is a circle said to be inscribed *in* a square or any other figure ? *(p. 19.)*
13. When four tangents make right angles with each other, what figure is formed ?
14. When is a polygon said to be inscribed in a circle ?

15. When a tangent is drawn from a given point, how many points of a circle can it touch?

16. What is the proportion between the radius of a Circle and one side of a hexagon inscribed in it?

17. What is meant by unequal circles? *(p. 20.)*

18. What is meant by a regular Polygon? *(p. 21.)*

19. What is a regular hexagon?

20. What is a regular pentagon?

21. What is a regular octagon?

22. How will you circumscribe a triangle with a circle?

23. How will you find the Centre of a circle to be inscribed in a triangle?

24. Where is the centre of an Arc which passes through two given points?

25. When you wish to draw several arcs through two given points, as in drawing the meridians on a map of the globe, how do you proceed?

26. When the base and other sides of a triangle are given, how will you find the point where the other two sides will touch?

27. If the sides cannot touch, how is the problem said to be?

FOURTH CLASS.

1. In drawing a right line, tangent to two circles, how must the two circles be placed? *(p. 25.)*

2. When are two circles said to intersect each other?

3. How many tangents may be drawn to two circles?

4. How many will be interior, and how many exterior?

5. Where will the interior tangents cross each other?

Ans. On a line drawn from the centre of one circle to the centre of the other.

6. How will you proceed to "*add two squares*," that is, to find a third square whose surface shall be as large as two smaller squares. *(p. 26.)*

7. After you have drawn your triangle, what will a semicircle drawn on the greatest side of the triangle touch? *(p. 25.)*

8. When the two smaller squares are equal, what sort of a triangle will be required to find the square equal to both of them?

9. If the great square and one of the small ones be given, how will you find the size of the other small one? *(p. 27.)*

10. How will you "*take half of a square?*" that is, how will you find two small squares which shall be equal to one large one?

11. What part of a circle is a Protracter?

12. How many degrees are graduated on a Protracter?

13. How will you proceed to graduate or mark the degrees on a Protracter? *(bottom of page 27.)*

14. What other way? *(top of p. 27.)*

15. Does the size of a circle increase the number of degrees into which it is divided? *(p. 28.)*

16. What is the difference then between the degrees of a large circle and those of a small one?

17. Is the angle between any two radii affected by lengthening the radii?

18. How many degrees of a circle form a right angle?

19. What is an angle of less than 90 degrees called?

20. What is an angle of more than 90 degrees called?

21. How will you find the size of an angle with the protracter?

22. What would two diameters of a circle drawn perpendicular to each other be called in geography ?

23. What are the ends of the axis called ? *(p. 29.)*

24. What are arcs of circles passing through both poles called in geography ?

25. Where are the centres of these arcs ?

26. What are the arcs called in geography, which are drawn nearly parallel to the equator ? *(p. 30.)*

27. Where will be the centre of these arcs ?

28. What is an Ellipse ?

29. How do you proceed to make an Ellipse ?

30. What Geometrical rule can you give for drawing an Ellipse ?

31. What amusing method is used ?

32. How may the figure be made more or less elliptical ?

33. How must you proceed to draw a Cone ?

34. What is the difference between a Cone and a Pyramid ? *(p. 32.)*

35. What is the height of a Cone ?

36. When is a Cone said to be upright ?

37. Why does the base of a cone appear to be an Ellipse ?

38. What is a Cylinder ? *(bot. of p. 32.)*

39. What is the height of a Cylinder ? *(p. 33.)*

40. When is a cylinder said to be upright ?

FIFTH CLASS.

1. How are the figures of the fifth Class formed ? *(page 34.)*

2. What is the general name of fillets, beads, congees, &c. ?

3. What is a Torus ? *(p. 35.)*

4. What is a Plinth ?
5. How is the profile of a Talon formed ? *(p. 36.)*

SIXTH CLASS.

1. What are the Four principal Orders of Architecture ? *(p. 40.)*
2. What are the three principal parts of an Order ?
3. Which of these parts is sometimes omitted ?
4. What supplies its place ? *(p. 41.)*
5. How is the Corinthian Order distinguished ?
6. How is the Ionick Order distinguished ?
7. How is the Dorick ?
8. How the Tuscan ?
9. By what other characteristicks are these orders distinguished ?
10. Of what Orders is the Composite composed ?
11. How were the proportions of the orders discovered and established ?
12. What proportions are common to *all* the orders ? *(p. 42.)*
13. Into what is the Pedestal divided ?
14. Into what is the Column divided ?
15. Into what is the Entablature divided ?
16. How does the height of the Tuscan column compare with its diameter ?
17. How does the height of the Dorick column compare with its diameter ?
18. How of the Ionick ?
19. How of the Corinthian ?
20. What, in measuring columns, is meant by a Module ?

21. Into how many parts is the Module divided in the Tuscan and Dorick orders ?

22. Into how many in the Ionick and Corinthian ?

23. What is meant by Intercolumniation ?

24. If you know the height, how can you find the Module ? *(p. 45.)*

25. What other method ?

26. What is a Pediment ?

27. What are Pilasters ?

PART SECOND.

THE ELEMENTS

OF

LINEAR PERSPECTIVE.

Although several authors have written excellent treatises on the Art of Perspective, it is to be feared that they have presupposed such an acquaintance with geometry, as is seldom attained by youth for whom *this work* is designed. A complete treatise is not intended, but merely such a familiar illustration of the first principles of perspective as a common mind, acquainted with the former part of this work, may be able to comprehend. All that has been attempted is the laying of a good foundation for future progress, should these few pages excite in the pupil a desire to know more of this useful and elegant art.

There is probably no one who has not remarked, that objects at a distance appear much smaller than their real size. The cause of this is to be found in the structure of the eye, and in the laws of vision. To illustrate these laws, draw a right line of any length with a pen, then place the rule parallel to the line; mark with the thumbs the length of the line upon the rule, and holding the thumbs there, stretch the arms at full length. Then begin gradually to draw the rule towards

the eyes, and it will be perceived that the space between the two thumbs appears longer than the black line, and before the rule reaches the eyes, the difference will be nearly as three to one.

This will lead the pupil to conclude, that objects of the *same* size appear the smaller the farther they are from the eye, and the larger the nearer they are to it, though the real size of the object is unchanged.

FIG. 1. PLATE II.

The *apparent* size of an object depends upon the angle formed by lines drawn from the extremities of an object to the eye, the eye forming the apex of the angle. Thus in fig. 1, let the circle represent the eye. Three arrows of *equal length* are placed at different distances from it. Lines are drawn from both extremities of each arrow, so as to cross each other at the same point in the eyes, and continue on till they touch the back of the eye. The pupil has been informed (p. 4.) that it is not the *length* of the sides, but the *opening* of the sides which determines the size of the angle. If the pupil will measure the angle, which the lines from the extremities of the nearest arrow to the eye form, (see page 28,) he will find it to consist of about 92 degrees, which are more than quarter of a circle. If he will then measure the angle formed by the lines from the second arrow, he will find it to consist of about 27 degrees. Finally, if he measure the angle of the third arrow, the farthest from the eye, he will find it to consist of only 14 degrees.

The lines of any angle if continued beyond the apex, as in this case, will form a second angle of the same size as the first. Of course the lines of the first angle, being extended beyond the apex to the back of the eye, form there a corresponding angle of 92 degrees, and

the other lines, extended in the same manner, form angles of 27 and 14 degrees.

The relative size of the angles is best represented on the back of the eye, where they are cut by a *single* circle, and where the distance between the lines gives the apparent size of the object as seen by the spectator. Thus, the distance between the dotted lines on the back of the eye is the *apparent* length of the farthest arrow, and so of the other lines, which may be easily traced to their proper arrows.

If the distance of the third arrow reduces the angle from 92 to 14 degrees, it must be evident that, if the arrow or object be much farther removed, it will form no angle at all with the eye, but will become a mere point, and then disappear or become invisible.

This point, at which the object ceases to form any angle with the eye, is called the *Vanishing Point* of the object; and that point in the eye where the lines cross each other is called the *Point of Sight.*

In figure 1, the arrows are represented of their *real* size, to show why they appear smaller as they recede. In figure 2, they are represented at their *apparent* size, to show the *vanishing point* to better advantage.

FIG. 2. PLATE II.

In the above figure the *real* size of the object is distinguished from the *apparent* size by dots, and as the *vanishing point* falls short of the last arrow, the conclusion is that this arrow is invisible to the eye of the observer.

The *vanishing point* is familiarly represented by the sides of a long and straight road, which seem to approach each other at a distance; or by the lamps of a long bridge, which, although in parallel lines, apparently meet when seen from either end of the bridge.

Perspective, then, is the art of drawing or representing any object on a *plane*, or *flat* surface, as the object appears to the eye of the spectator.

The simplest way to represent an object in perspective is to stand before a window, and, holding the head still, to draw on a pane of glass the outline of any object seen through it. But a more convenient apparatus is generally used.

This, and some of the more important terms used in Perspective Drawing, the pupil must endeavour to understand.

1. *The Perspective Plane* is an upright square of glass, usually framed like a picture, with a base, so that it can stand up alone. This is placed between the eye of the spectator and the object to be drawn, and as the drawing is sometimes made directly upon it, it is sometimes called the *Picture* or the *Plane of the Picture.*

2. *Visual Rays* are lines drawn from every part of the object, through the Perspective Plane to a point in the spectator's eye, which point, it has been said, is called the *Point of Sight.*

3. *The Horizontal Line* is a line drawn directly across the Perspective plane at the height of the spectator's eye, and this may be of any height, although it is customary to draw the line about one third from the base or bottom of the Perspective Plane.

4. *The Centre of the Picture* is that point on the Perspective Plane, where a line, drawn from the spectator's eye to the Perspective Plane, would strike the Horizontal Line. This point is generally placed as near the centre of the Perspective Plane or Picture, as possible, and hence its name.

5. *The Prime Vertical Line* is a perpendicular line raised on the base of the picture, and passing through that point which is called the Centre of the Picture.

It is of course perpendicular to the Horizontal Line also.

6. *The Points of Distance.* One, called the *distance of the picture*, is the distance of the eye from the centre of the Perspective Plane. The other called the *Vanishing distance*, is the distance from the eye to the Vanishing point on the Perspective Plane.

7. *The Ground Plane* is the table or any flat horizontal surface on which the Perspective Plane is supposed to stand.

8. *The Base Line* is a line necessarily marked across the Ground Plane by the base or bottom of the Perspective Plane.

FIG. 3. PLATE II.

This figure represents a road with passengers at different distances on it.

The Base Line is at the bottom of the figure.

The *Horizontal Line* cuts the four passengers in the middle, and is always parallel to the *Base Line.*

The *Vanishing Point* and *Centre of the Picture* are in this case the same point, where the lines converge on the Horizontal Line.

The Prime Vertical Line is the perpendicular raised on the *Base Line*, and passing through the Centre of the Picture.

Now to give each figure its relative proportion according to its distance, draw vanishing lines to the vanishing point from the extremities of the nearest figure, and in the angle thus formed will be found the heights of all the other figures. To find the height of a figure on any part of the road, only lead off a horizontal line, parallel to the base line, for the foot of the object, and the height is found by raising a perpendicular from the horizontal until it strikes the other converging or *van-*

ishing line. The dotted lines in the cut will illustrate this better than any description.

FIG. 4. PLATE II.

Suppose it be required to find the *perspective distance* of nine trees equidistant from each other. Draw the *Base Line* just the real length of the row of trees, or longer, at pleasure. Then draw the *Horizontal Line* longer than the base line. From the left end of the base line draw a *Vanishing Line* to any point on the horizontal line. Then taking the length of this vanishing line, take a portion of the Horizontal Line to the left of the *Vanishing Point*, equal to the vanishing line in length. On the *Base Line* measure the *exact* length of the row of trees, and divide the *Base Line* into exact portions according to the number of trees, and place a dot at each distance. Then draw a line from each of these dots to the point on the left of the *Horizontal Line*, and the points where these lines intersect or cross the *Vanishing Line* are the perspective positions of the trees. If you wish to regulate the height of the trees, draw another vanishing line from the top of the tree on the *BaseLine* to the *vanishing point*, and the distance between the two vanishing lines will be the height of the trees, as is shown by the dotted line in the figure.

FIG. 5. PLATE II.

Figure 5 represents the perspective of a square, one of whose sides is parallel to the *base line.* First draw the *base* and *horizontal lines*, then from the two angles of the square which touch the base line carry the two vanishing lines to the vanishing point on the horizontal line. From the same angles draw two lines, one to the right and the other to the left of the vanishing point, and at equal distances on each side of it. Then draw a line

to connect the two points where these two lines intersect the vanishing lines, and the square is finished.

To draw the perspective of a second square, place one foot of the dividers at those angles of the first square which touch the *base line ;* draw the dotted quadrants or quarter circles ; and, from the points where they strike the base line, draw oblique lines to the points of distance on each side of the vanishing point, and the four points where they intersect the vanishing lines will be the four corners of the next perspective square ; and you have only to connect these points by lines parallel to the base line. Pursue the same course in drawing the third square, and so on.

FIG. 6. PLATE II.

To draw the perspective of a solid body as a Cube or Prism. First, by directions under fig. 5, draw the perspective *base,* then raise perpendiculars to the *base line,* and by uniting their tops form that face of the cube or prism which is parallel to the *Perspective Plane,* and is the nearest face to the spectator's eye or point of sight. From the four corners of this face of the cube draw lines to the vanishing point, following the direction of the right and left sides of the perspective base. Raise perpendiculars from the two distant points of the *base* until they touch the two *upper* vanishing lines, and connect these two points by a right line, and the perspective cube is formed.

To draw a second Cube, draw a second base as in fig. 5, raise perpendiculars, and proceed as with the first cube.

In the directions for drawing a Cone (Part I, Class 4) it was remarked that although the base was an exact circle, the laws of perspective required that it should be represented as an ellipsis or oval. The mode of representing a *square* in perspective has been shown ;

the next figure illustrates the rules for drawing a *circle* in perspective.

FIG. 7. PLATE II.

Draw the Circle and enclose it in a square. Draw parallels to the sides of the square where the diagonals cut the circle, then a parallel to the sides passing through the centre of the circle. From the points, where these parallels strike the *base line*, lead off vanishing lines to the *vanishing point*. Follow the directions given in fig. 5, for completing the *squares;* but the *circles* must be drawn *by the eye* through the eight points formed by the intersection of the diagonals and vanishing lines. Of course, more vanishing lines may be made if the circle be large, and they are necessary.

It will be noticed, that in this figure one half of the lines is dotted. The object of this is to show that, in drawing the arches of a bridge in perspective, the easiest way is to draw circles, the arch being half of a circle, and represented in the figure by the lines *not dotted*, the *prime vertical line* representing the surface of the water.

This figure may serve also to show the perspective of a *Rhomb or Lozenge*, represented by the diagonals of the squares. The Piers of the bridge deform the second rhomb, but, if no space be left between the squares or circles, the rhomb will be perfectly formed.

FIG. 8. PLATE II.

From the five angles of the *Polygon*, draw as many perpendiculars to the base line, and let the left hand perpendicular extend far enough down to intersect horizontal lines from the five angles abovementioned. Then from the points where the five perpendiculars strike the base line, lead off five vanishing lines to the vanishing

point in the horizontal line. From those points where the horizontal lines strike the left hand perpendicular, describe arcs of circles to the base line. From the points where these arcs strike the base line,lead off lines directed towards some one point on the horizontal line, but let them stop at the first vanishing line they strike, and from the point where they strike this vanishing line, draw parallels to the base lines, and by the figure it will be seen that they will strike the other vanishing lines in the points which form the angles of the perspective polygon. Draw lines to these points, and the figure is formed.

FIG. 9. PLATE II.

To draw the perspective of a house of which one side is parallel to the perspective plane, and in all similar drawings, it is necessary to have the exact measurement of every part of the building which is to be represented.

Having drawn the base line C D H and the horizontal line A B at the height of a man's head above it, that is, about 5 feet 6 inches, you may fix the centre of the picture at G on the horizontal line. Then raise perpendiculars on the points C D, equal to the *actual* height of the building as previously laid down on a proportional scale of parts, and connect these perpendiculars by the horizontal line F E, parallel to the base line. This will complete the *front* of the building, or that part facing the spectator's eye.

To represent the *end* of the building, draw the *vanishing lines* E B and D B. Ascertain the *real* width of the end, and mark it on the base line, say from D to H. Draw a line from H to the centre of the picture G, and the point where it cuts the vanishing line D B at I is the perspective width of the end. On the point I raise a perpendicular till it strikes the other vanishing

line at K, and you have the other corner of the building.

Draw the diagonals D K and E I, and the point L where they intersect will be the *centre* of the gable end.

Having measured the *actual height* of the gable end, continue the perpendicular D E till it reaches M, the actual height. Then draw the line M B. Erect a perpendicular on the centre of the gable end L, and the the point N, where it intersects the line M B, will be the point of the gable end. Then draw the lines N E and N K, and the end is completed.

To draw the Chimney, find its *actual* height above M, the actual height of the gable end, and continue the perpendicular D E M to O. Draw the line O B, then, on each side of the centre P L, lay off on the base line two spaces P*a* and P*b* each equal to half the *real* breadth of the chimney, and raise the perpendiculars *ac* and *bd*.

To find the *thickness* of the chimney, lead off a line from O to Q equal to its *real* thickness. Draw the line Q B. Lead a horizontal from *c* till it strikes the line Q B at *e*; do the same from *g* to *f*; connect *e* and *f* by a perpendicular, and the perspective of the chimney is finished.

To draw the other gable end, you must suppose the house to be transparent, and proceed exactly as you did with the first. Then connect the points of the gables, and the line N R will form the ridge of the house.

The door and windows of the side parallel to the perspective plane must be drawn according to their actual dimensions, the rules of perspective only affecting the thickness of their edges.

FIG. 10. PLATE II.

To draw a house which stands *oblique* to the picture, that is, one which has no side parallel to the picture or

Perspective plane, begin with the base line C D and the horizontal line A B. Take E the corner of the building nearest to the spectator's eye, and draw the line E B for the bottom of one side of the building.

Then, to find the *Vanishing point* of the lines of the other side, from the *Centre of the picture*, which you may fix at F, draw the perpendicular F G equal to the *Distance of the picture*. Then draw the line G A at right angles to G B, and the point A, in which it cuts the horizontal line, will be the vanishing point of the other side of the building. To this point, therefore, draw the line E A for the bottom of this side of the building.

In order to find the apparent width of each side, it is necessary to have a distance point for each side. Take the space from A to I, equal in length to the line A G, the point I being the distance point of the side E A. In like manner with the distance B G mark the space B H on the horizontal line, the point H being the distance point of the side E B. On the base line measure the space E C equal to the real width of the side E A, and from the point C draw a line to the distance point I, which, cutting the line E A at L, will give the space L E, the perspective width of that side. In like manner measure off E D the *real* width of the other side, draw the line D H, and the space E N is the perspective width of this side.

From the corner E erect the perpendicular E M, the actual height of the house ; draw the line M A for the top of the building ; raise a perpendicular on the point L till it strikes the line M A at K, and you have one front of the building completed. Do the same by the other side and you have M E O N, the other front.

Cross two diagonals to find the centre of the gable end near I. Carry the perpendicular E M to P, the real height of the point of the gable end. Draw the line P B, raise a perpendicular on the *centre* of the gable

end near I, and the point *a* where it strikes the line P B will be the perspective point of the gable end. Draw the lines M *a* and O *a*, and the gable end is completed.

Having found the point Q of the other gable end, by the rules given under fig. 9, draw the line K Q for the slanting side of the roof, and the line *a* Q will form the ridge of the house.

Mark the actual height and length of the door or window upon the perpendicular line E M, and draw lines from these points to A. The perspective height of the door and window will be found between these lines. To find the relative distance of the door and window from the end of the building, mark off the *real* distance on the base line and draw a line from that point to the point of distance I or H, as the case may be, and the point where this line strikes the lower vanishing line of the door or window will be the perspective distance of the side of the door or window.

FIG. 11. PLATE II.

To draw fig. 11, first draw the front of the arcade D Q E G H and A R C. Find the common centre O on the centre of Q G, at the height of the base of the arch. From the centre O draw a line towards the point of view V until you strike the point N, the centre of the perspective arch L M, which will terminate the proposed arcade.

If the thickness X H of the first arch (if the arcade is composed of several arches) project, as often happens, then, on the perspective depths X and 3, raise the perpendiculars X Y and 3, 2, to the perspective line of the top of the walls. On the point U, the centre of the opening of the arcade, raise the perpendicular U E. To

the point of view V, draw the two lines E V and U V and the point where these two lines are cut at T by the line X 3 raise a second perpendicular till it strikes P on the line E V. On the tops of the perpendiculars X Y and 3, 2 finish the dotted arch passing through the point P and you have the perspective width, height, &c. of the first arch.

QUESTIONS ON PART II.

1. On what does the *apparent* size of an object depend?
2. Is the angle increased or diminished by the distance of the object?
3. When does an object become invisible?
4. What is meant by the *Vanishing Point*?
5. What is meant by the *Point of Sight*?
6. What is meant by *Perspective Drawing*?
7. What is meant by the *Perspective Plane*?
8. What are *Visual Rays*?
9. What is the *Horizontal Line*?
10. What is meant by the *Centre of the Picture*?
11. What is the *Prime Vertical Line*?
12. What are the *Points of Distance*?
13. What is the *Ground Plane*?
14. What is the *Base Line*?

The teacher should now take figure third and ask the name of each line upon it. He should also require each pupil to draw a similar figure, but not of the same dimensions. If the figure be drawn with chalk on a black board before the class, it will be easy to require each pupil to draw a portion of the figure to show that he un-

derstands the application of the directions given under the figure.

The same course must be pursued with every other figure. By frequently drawing the figures the pupil will be able to answer the question, "How must you proceed in drawing this or that figure?" As, at first, perfect exactness is not required, the necessary knowledge of terms may be acquired by drawings made without instruments.

It will be seen by the examples of Perspective Drawing here given, that the pupil will not need a *real* Perspective Plane or plate of glass, if he can *imagine* one to be between his eye and the object; and, as the teacher may vary the exercises *ad infinitum*, by requiring figures to be drawn of given dimensions, it is unnecessary to give more examples.

PROBLEMS

IN

Arithmetick and Geometry.

It is easy to unite two branches of instruction, which are so important and so analogous. Artists and mechanicks ought to be able themselves to measure their work, whatever it may be ; and to draw plans, to make contracts for work, to calculate the price and quantity of materials necessary for the work ; and, in fine, to make all the estimates required by the art they practise.

To enable them to do this, we shall unite the elements of Geometry and Arithmetick, explain the problems and rules of most common occurrence, and add numerical examples to illustrate their application. The master will vary the examples at pleasure.

Inches are divided into tenths, hundredths, thousandths, &c. and calling the inch unity, or a whole, we place a comma at the right hand of it to separate the fractions or parts. For example, to express 8 inches and 6 tenths, we write 8,6 ; for 9 inches and 72 hundredths, we write 9,72 ; for 10 inches and 626 thousandths, we write 10,626, and so on. If there be no whole inches, a cipher is put in the place of inches, and the comma as before, thus, 0,382 stands for 382 thousandths of an inch, or as the first column at the right of

the comma is tenths, the second hundredths, and the third thousandths, we may read it, 3 tenths, 8 hundredths, and two thousandths of an inch ; but the former way is preferable.*

In Addition and Subtraction, columns of the same name should be placed under each other, and the calculation made as if there were no decimal fractions. The following examples will show the use of this rule.

Addition.	*Subtraction.*	
432,178	324,15	30,4
17,231	187,3	19,28
9,4	136,85	11,12
83,502		
7,08		
549,391		

Add the following sums :

36,075	8,1	4,44
9,6	28,04	8,176
345,56	686,008	0,43
86,115	5,16	10,08
6,8	82,686	2,5

Subtract the following :

68,06	4,85	15,908
17,67	3,9	12,819

The master or monitor may vary such sums at pleasure.

* After thousandths, come ten thousandths, hundred thousandths, millionths, &c. but for ordinary uses we seldom come down to so small a fraction.

Multiplication is performed as if there were no comma; but in the sum total, as many figures must be cut off at the right hand of the comma, as are cut off in both the multiplier and sum multiplied. For example:

4,37	183,2
2,3	0,24
1311	7328
874	3664
10,051	43,968

Multiply	37,04	by	4,8
	3,96	by	0,84
	18,5	by	5,18
	468,007	by	8,14

In Division, add ciphers at the right of whichever of the two numbers has the least number of decimal figures, that the *dividend* or sum to be divided, and the *divisor* or sum to divide by, may have an equal number of them; then pay no regard to the comma, and divide as in ordinary arithmetick.

When you have found the *wholes* of the quotient, place a comma after them, and then find the decimals by putting a cypher at the right of the remainder, and dividing anew, you will then have the first figure after the comma in the quotient. Add another cipher to the remainder, and you will have another decimal figure, and so on.

EXAMPLES.

To divide 10,051 by 4,37 I write thus :

```
4370) 10051 (2,3
       8740
      -----
      13110
      13110
      -----
          0
```

That is, I add a cipher to 4,37 hundredths, to make them thousandths, because there are thousandths in the dividend.

In the above sum, the answer is, 2 wholes and 3 tenths.

Again, divide 154,3 by 21,26.

```
2126) 15430 (7,25
      14882
      -----
        5480
        4252
        -----
        12280
        10630
        -----
         1650 remainder.
```

The answer is 7 wholes, and 25 hundredths. It is unnecessary to carry the remainder to any lower fraction.

Divide	36,75	by	8,4
	460,8	by	46,54
	84,968	by	8,68
	166,14	by	19,762
	86,4	by	4,86

When you have obtained two or three decimal figures in the quotient, it is useless to carry the calculation any further, as they will be too small.

We shall now endeavour to apply these principles.

SECTION I.

OF LINES.

Problem I. *To find a side of a rectangular triangle, the two others being known.*

Rule. Multiply by itself each of the known sides, then add them together if you wish to find the greater side; and subtract the lesser number from the greater if you wish to find one of the lesser sides. Then you will have the same result as if you had multiplied the unknown side by itself. Of course, you have only to find what number, multiplied by itself, will give this result.

Example 1. The smaller sides of a rectangular triangle, (figs. 12 and 13, Class I.) are one 3, and the other 4 inches, find the larger side.

3	times	3	are	9
4	times	4	are	16
These added make				25

5 multiplied by itself makes 25, and the greater side or side required, must be 5 inches.

Example 2. In a rectangle, (1st Class, fig. 14,) it is known that the base is 8 inches, 54 hundredths, the

height is unknown, but the diagonal (a right line drawn from corner to corner) is found by measurement to be 15 inches, 32 hundredths. What is the height ?

Note. A diagonal cuts the *oblong square* or rectangle into two rectangular triangles, of which the height above required is one of the smaller sides.

8,54	15,32	As a smaller side is required, subtract the known smaller from the larger.
8,54	15,32	
3416	3064	
4270	4596	234,7024
6832	7660	72,9316
	1532	
72,9316		161,7708
	234,7024	

It remains to find a number, which multiplied by itself will give 161,770. A few trials will show that this is (as near as possible) 12,719 as may be found by multiplying this number by itself. The height then, is 12 inches, and 719 thousandths of an inch.

Example 3. Find the height of an isoceles triangle, (1st *Class*, *Prob.* 27.) whose base is 52 and the equal sides, 87. The perpendicular, drawn from the summit, cuts the base in halves, and is one side of a rectangular triangle, of which

the base is half the larger one, or . .		26
The great side of the new angle, which was one of the equal sides of the isoceles, is		26
	87	156
	87	52
From 7569		
Take 676	609	676
	696	
6893		
	7569	

A few trials will show, that the height required is, 83 nearly, for 83 times 83 are 6889.

4. The smaller sides of a rectangular scalene triangle, (1st Class, fig. 13,) are 5 and 7 inches, required the larger side. Ans. 8,6 in. nearly.

5. One small side of a rectangular scalene triangle is, $8^{in.}$,3 and the other $4^{in.}$,8 what is the size of the third side ? Ans. 9,59 in. nearly.

6. The two equal sides of a rectangular isoceles triangle, are 4,8 in length, what is the length of the base ? Ans. 6,785 in. nearly.

7. The base of a rectangle (Ex. 2) is 7,15 ; the diagonal 13,25 ; required the height (that is, the third side of the triangle.) Ans. 14,14 in. nearly.

8. The base of a rectangle is 4,75 and the height 7,25 required the diagonal, or longest side of the triangle. Ans. 8,67 in. nearly.

9. What is the height of an isoceles triangle, of which the base is 6 inches, and the equal sides $3^{in.}$,8 each ? Ans. 2,33 in. nearly.

The instructer may increase these examples at pleasure.

Problem II. *To find the circumference of a circle when lengthened out into a right line.*

Rule. Multiply its diameter by 3, and add a seventh of a diameter.

Example 1. The diameter of a circle is $4^{in.}$,523.

	4,523
	3
	13,569
A seventh of 4,523 is	,646
The circumference is	14,215

2. The width of a basin is $5^{in.},5$ how long must a string be to reach round it ?

$$\begin{array}{lr} & 5,5 \\ & 3 \\ \hline & 16,5 \\ \text{A seventh of } 5,5\ \ldots & 0,786 \\ \hline \text{Length of the string, } \ldots & 17,286 \text{ the circumference.} \end{array}$$

3. The diameter of a circle is 4,45, what is the circumference ? Ans. 13,98 inches.

4. The diameter of a ring is 1,5, what is the circumference ? Ans. 4,7 inches.

5. The diameter is 4,17, what is the circumference ? Ans. 13,1 in.

PROBLEM III. *The circumference being known, to find the radius.*

RULE. Multiply the circumference by 0,159 and you will have the radius.

Example 1. To find the thickness of a column, its circumference has been measured with a string and found to be 12,542—required the radius.

$$\begin{array}{r} 12,542 \\ 0,159 \\ \hline 112878 \\ 62710 \\ 12542 \\ \hline 1,994178 \text{ radius.} \end{array}$$

If 1,994 thousandths be the radius or half diameter, 3,988 will be the whole diameter of the column. Six figures are separated, because there are three in the multiplier, and 3 in the multiplicand. The three right hand decimals are unimportant.

2. The circumference of a column is 10,5 what is its radius? what its diameter? Ans. R. 1,67 D.3,34.

3. The circumference of a ship's mast is $136^{in.}$,15 what is its diameter? Ans. 43,28 in.

4. The circumference of a wheel is 48,75, what is its radius and diameter? Ans. R. 7,75 D. 15,5.

SECTION II.

OF SURFACES.

PROBLEM I. *To find the surface of a parallelogram.*

RULE. The surface of a parallelogram (fig. 16,) or rectangle (fig. 14,) is found by multiplying the base by the height. That of a square is found by multiplying one of the sides by itself.

Example 1. A rectangle has $2^{in.}$,24 for its base, $4^{in.}$,31 for its height, what is its surface?

```
    2,24
    4,31
    ----
     224
    672
   896
  ------
  9,6544 surface.
```

That is, 9 square inches, and 65 hundredths of a square inch.

2. A room is 154,6 inches long, and 75,3 wide, what is its surface or area?

```
    154,6
     75,3
    -----
     4638
    7730
   10822
 --------
 11641,38
```

That is, 11641 square inches, and 38 hundredths of a square inch.

3. A yard of a rectangular form, is 2023 inches long, and 1145 wide, what is its area or surface ?

4. A house is 388 inches long, and 146 wide, how many square inches of ground does it cover ?

PROBLEM II. *The surface of an upright prism without including the two bases, is found by multiplying the height by the circumference of the base.*

All the lateral faces or sides of the body are rectangles, and come under the preceding rule.

Example 1. A man wishes to plaster the walls of the room mentioned in No. 1 of the last problem. These walls are 84,6 inches high, how many superficial inches do they contain ? The room forms a parallelopiped, 2023 inches long, 1145 wide, and 84,6 high. Double the width and length, and add them together, and you have the whole length of the walls, 6336 inches. Multiply this by the height, and you have the answer in square inches.

```
1145              6336
1145              84,6
2023             -----
2023             38016
----            25344
6336           50688
               --------
               536025,6 Ans.
```

2. A man wishes to cover the walls of a room with cloth. The length of all the sides added together is 675 inches, 7 tenths, the height is 98,4 the cloth is 32 inches wide; how long a piece will cover the walls?

Multiply the length by the height, to find the surface or *superficies* to be covered. The cloth then must have a length which multiplied by its breadth will give the same superficies, and this is found by dividing the superficial contents of the walls by the width of the cloth. Paper hangings may be measured in the same way.

Ans. 2077 inches or 57 yards.

If the prism be oblique, its surface is found by taking that of all the parallelograms which form it.

PROBLEM III. *To find the surface of a triangle.*

RULE. Multiply the base by the height, and take half of the result.

If you please, you may take half the base or half the height, before you multiply, and then there will be no need of halving the result. A triangle is always the half of a parallelogram of the same base and height.

The pupil, it is to be hoped, need not be told that 12 inches make a foot, and 3 feet or 36 inches an English yard. We advert to this, because we have hitherto only measured by inches, and it may be well to say that when feet or yards, inches and decimals are named together, the yards or feet must be brought into inches. To do this, multiply the feet by 12, and the yards by 36. This however is not necessary, when only feet or yards are named, and the decimals are parts of them, and not parts of inches.

Thus, 8 feet, 4,8 inches are the same as 100,8 inches.
6 yds. 4,5 inches are equal to . . 220,5 inches.

Example 1. Required the extent of a field of a triangular shape, of which one side taken for the base, is 154

yards long, and the height (a perpendicular drawn from this base to the point or summit of the opposite angle) 83 yards. Multiply 77 (that is, half the base) by 83, and I have the answer, 6391 square yards of surface.

The superficies, or surface of a polygon, or a pyramid, is found by taking separately the surfaces of the triangles of which they are composed.

2. An irregular court has a quadrilateral *(four sided)* form. To find its surface, I measure one of the diagonals which I find to be 129,7 yards. I draw perpendiculars from the angles opposite this diagonal, one of which I find to be 52,5 yds. and the other, 41,8 yds. I consider the court as forming two triangles, and find their superficies separately, thus :

First triangle . .	129,7	Second triangle . .	129,7
Height	52,5	Height	41,8
	6485		10376
	2594		1297
	6485		5188
	6809,25		5421,46
			6809,25
			2) 12230,71
		Square yards, ...	6115,355

But as this requires two multiplications, it is a shorter way to add the two heights, 52,5 and 41,8 which gives 94,3 of which the half, 47,15 multiplied by 129,7 the base, gives 6115,355 square yards as above.

3. A four sided polygon has a diagonal of 66 feet, 3,8 inches ; the height of one triangle is 22 feet, 6,6 inches ; and of the other, 18 feet, 8,2 inches ; required the superficial contents of the polygon.

Ans. 195880,9 inches, or 1360 square feet.

If the polygon be regular, draw lines from the centre to two of the neighbouring angles, find the contents of the triangle thus formed, and multiply by the number of sides, which being all of a size, will make triangles of the same size.

4. A hexagonal basin has equal sides of 3,34 inches each. Its width from the centre of one side to the centre of the opposite side, is 4,88 inches. As half of this line drawn from side to side is the height of one of the triangles, the height is, 2,44 inches. Multiply the base, which in this case is the side, by half the height, and you have the answer. Ans. 24,42 square inches.

Problem IV. *To find the surface of a trapezoid.* (fig. 3.)

Rule. Take half the sum of the two parallel sides, and multiply by the height.

Example 1. A roof in the form of a trapezoid, has one of its parallel sides 44,7 feet, and the other 33,5 feet in length, and the height is 9,4 feet, what is the superficies? Ans. 367,54 feet.

2. How many slates 15 inches long, and 12 wide, will cover the above roof? Ans. 294.

Note. No allowance is here made for one slate's projecting over another, &c. This would only increase the size of the roof, but not alter the mode of calculation. Change the *feet* of the roof into *inches*; find the square inches in each slate, and divide the number of inches in the roof by the number in a slate.

Problem V. *To find the surface, or superficial contents of a circle.*

Rule. Multiply the radius by itself, and then the product by $3\frac{1}{7}$ (or 3,143.)

Example 1. A circular basin has a radius of 8,3 inches.

8,3	68,89
8,3	$3\frac{1}{7}$
249	20667
664	984
68,89	216,51 square in.

2. The radius of a cistern is 3,45 feet, what is its surface ? Ans. 37,40 sq. ft.

3. I have measured round a basin, and find the distance 28,5 inches, and conclude by Problem III, Sect. 1, that the radius is 4,53. The rest of the work is done like the above example. Ans. 64,49 sq. in.

4. The circumference of a circle is found to be 4,85 feet, what is its superficial contents ? Ans, 1,76 sq. ft.

Problem VI. *To find the surface of an upright cylinder.* (4th Class, fig. 12.)

Rule. Multiply the circumference of the base by the height. As the base is a circle, knowing the radius, it is easy to find the circumference. (Prob. 2, Sect. I.)

Example 1. A painter has painted a circular hall, the walls are 3,4 yards high, and the diameter of the hall is 54,2 yards, how many square yards has he painted ? Ans. 579,156 sq. yds.

If there be doors and windows, they are calculated separately, and subtracted from the amount. To find the contents of mouldings, measure them with a piece of string or parchment, which will yield to their various curvatures, and if you please, add their width and surface to the first amount.

SECTION III.

OF VOLUME.

PROBLEM I. *To find the volume of a prism or cylinder.*

RULE. Multiply the *base* by the height, and the product will be the number of cubes (that is, solid squares) contained in the body.

Note. The length, breadth, and height, must always be expressed in the same sort of measure, whether it be yards, feet, or inches; if they are not so expressed in the proposition, they must be reduced before any thing else is done.

Example 1. A wall is 2,8 yards high; 0,6 thick; and 104,5 yards long; how many cubick feet does it contain?

2,8 multiplied by 0,6—gives 1,68 square yds.
1,68 multiplied by 104,5—gives 175,560 square yds.

2. A pile of wood in the form of a parallelopiped, is 54,8 feet long; 22,3 feet wide; and 37,1 feet in height; how many cubick feet does it contain?

Multiply these three numbers together, and the answer will be 45337,684 cubick feet.

8. A cylindrical caldron is 8,3 feet deep, and 13 feet wide; what is its *capacity* (that is, how many cubick feet will it contain?)

The width or diameter is 13, the radius must be 6,5. Multiply 6,5 by 6,5 and the product by $3\frac{1}{7}$ (Sect. II. Prob. 5,) and you have the superficies of the base, which multiply by the height 8,3 and you have the capacity required. Ans. 1102,124 cubick feet.

4. A common brick is generally 8 inches long, 4 wide, and two thick. What is its volume ? How many will it take to make a cubick foot of masonry ?
Ans. Vol. 64 sq. in. Cubick foot 27 bricks.

5. How many bricks will it take to construct a wall, 300 feet long, 6 feet high, and 1,5 thick ?

Ans. 72900.

Note. It will be seen that this and the preceding calculation make no allowance for mortar.

6. A well is 6,9 yards deep, and 1,2 yards in diameter. I wish to make a wall in it, 0,4 yards thick ; how many cubick feet of stone will build it ?

Calculate the well as if it were to be entirely filled up. Its diameter being 1,2, its radius must be half that, or 0,6 tenths ; to this add, 0,4 tenths, the proposed thickness of the wall, and you have 10 tenths, or a whole yard, for the radius of the well.

Then subtract the empty part of the well, which forms another cylinder, whose radius is 0,6 tenth, as above mentioned.

1 multiplied by 1 and by $3\frac{1}{7}$ gives 3,14 the base of the first cylinder.

0,6 multiplied by 6 and by $3\frac{1}{7}$ gives 1,13 for the base of the smaller cylinder, which subtracted from 3,14 leaves 2,01 which multiplied by the height, gives the answer. Ans. 13,869 square yards.

7. How many bricks would the above wall require ?

Ans. 10110,5.

Problem II. *To gauge a cask.*

Rule. Take the superficies of the base, and twice that of the centre at the bung hole, (Prob. 3, Sect. I.) add the two amounts, and multiply the product by a third of the length.

Note. All these measurements should be of the inside or clear, otherwise the thickness of the wood will be included.

Example 1. A cask is 31 inches in diameter at the bung, 28 at the base or head, and its length is 54 inches. What is its capacity?

The radius of the base is . . . 14
The radius of the bung is . . . 15,5

14 times 14 multiplied by $3\frac{1}{7}$	616
15 times 15,5 multiplied by do.	755
Repeated	755
Amount, neglecting fractions,	2126

Multiply this by 18, which is a third of the length, and you have the answer, 38268 cubick inches.

There are 231 cubick inches in a gallon. To find then how many gallons the above cask contains, divide its contents by 231.

2. Required the contents of a cask whose diameter at the bung is 38,6 inches, at the head or base 33,4 and whose length is 63,9 inches. Ans. 68540,783 cub. in.

3. Required the contents of a cask whose *circumference* at the bung is 90 inches, at the base 80 inches, and whose length is 48 inches. Ans.284115 cub.in.1229 gals.

Problem III. *To find the volume or solid contents of a pyramid or a cone.*

Rule. Multiply the base by the height, and take a third of the product.

Example 1. A loaf of sugar has a base 4,8 inches in diameter, and is 12,3 inches in height. What are its contents?

Find the contents of the base by multiplying the radius or half diameter 2,4 by 2,4, and the product by $3\frac{1}{7}$, (Sect. I. Prob. 5.) Multiply the latter product by the height 12,3 and divide the product by 3 to find a third of it, which will be the answer. Ans. 74,21 cub.in.

2. The base of a pyramid is a pentagon of equal sides, (2d Class, fig. 12.) each side being 14 inches. The height is 22 inches. What are its solid contents?

3. The base of a pyramid is a right angled triangle, (1st Class, fig. 9.) of which the base, or longest side, is 13 inches, the shortest 6. The height of the pyramid is 19 inches. Required the solid contents.

Find the superficies of the base by Prob. I, Sect. I.

PROBLEM IV. *To find the volume or solid contents of a truncated cone of parallel bases.*

Note. A truncated cone is one whose top is cut off.

RULE. Multiply the radius of each base by itself, and multiply them together. Add together the three products. Multiply the whole sum by the height, and add to this product a third of a ninth of it, (that is, a 27th.)

Example 1. A Bucket is 14,5 inches in diameter at top, and 11,2 at bottom. Its *perpendicular* height is 17,5 inches. Required its solid contents.

14,5 multiplied by 14,5 gives	210,25
11,2 multiplied by 11,2 gives	125,44
14,5 multiplied by 11,2 gives	162,40
	498,09
498 multiplied by the height 17,5 gives . . .	8715
A ninth of which is 968,3	
And a third of the ninth is	322,7
Cubick inches,	9037,7

2. How many such buckets of water would it take to fill the caldron mentioned in Example 3, Prob. I. of this Sect.?

END.

ERRATA.

PAGE 64 LINE 9, for centre of the gable end E, read L.

" 64 " 22, for connect *c* and *f* read *e* and *f*.

The Figures of the three first classes of Part I. are copied from the French Original; those of the fourth and fifth classes, from drawings by pupils of the Monitorial School. *Plate First* was designed by the Translator for the purpose of exhibiting at one view the four principal orders *with the same module*, thus affording an opportunity of comparing their relative height, grace, and strength. *Plate Second* was also designed by the author of Part II, and the expense of this plate and the very considerable enlargement of this edition, must be the publishers' excuse for the comparatively small increase of price.

☞The difficulty of obtaining chalk suitable for drawing or writing on boards painted black, has induced the author to procure and keep on hand a quantity of *Artificial French Chalk,* in crayons of a convenient size, at 25 cents a pound. This chalk has no hard particles in it, wears well, and does not waste.

CORINTHIAN IONIC DORIC TUSCAN

Fig. 1.

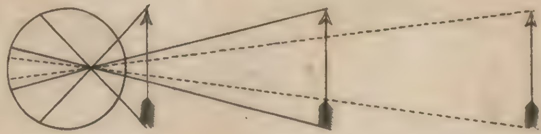


Fig. 2.

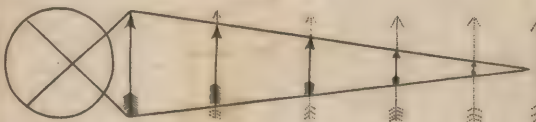


Fig. 3.

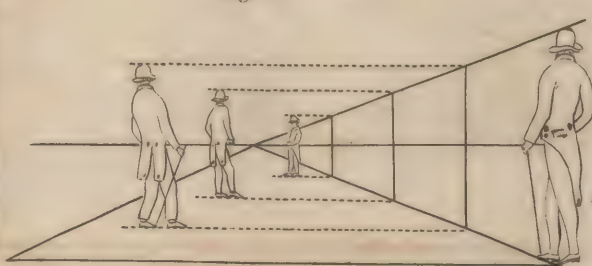


Fig. 4.

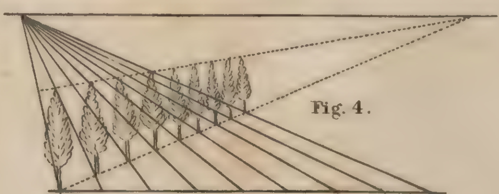


Fig. 5.

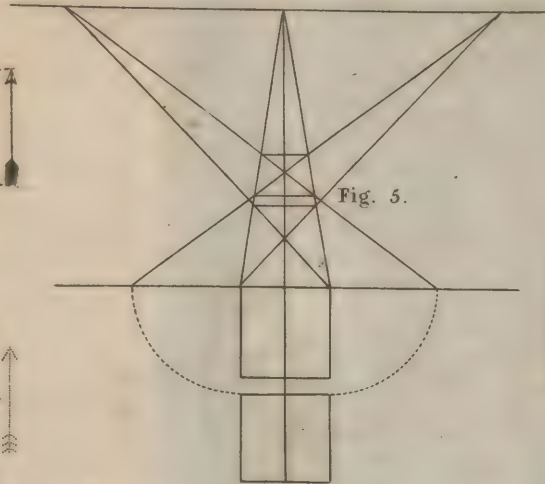


Fig. 6.

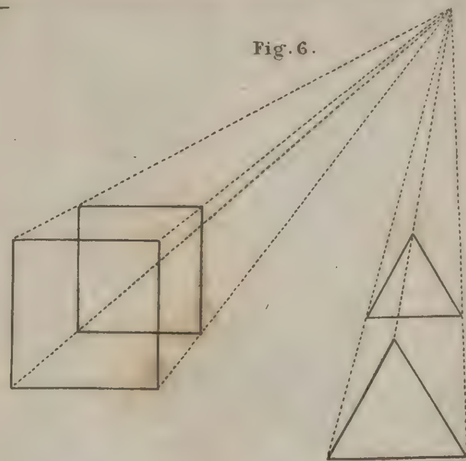


Fig. 7.

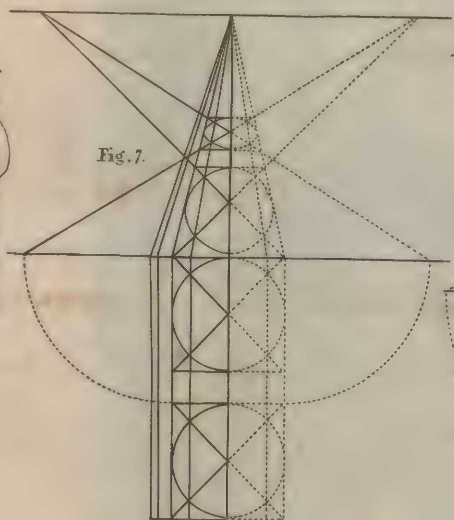


Fig. 8.

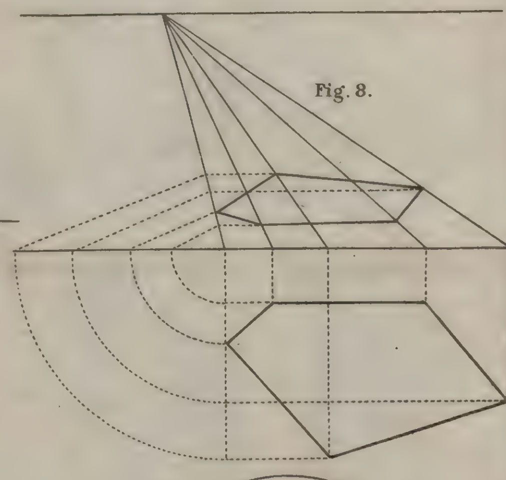


Fig 9

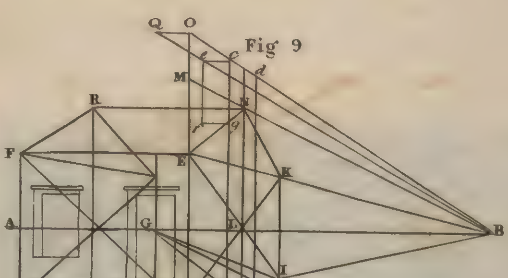


Fig. 10.

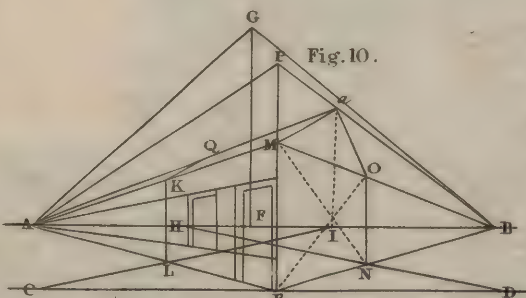


Fig. 11.